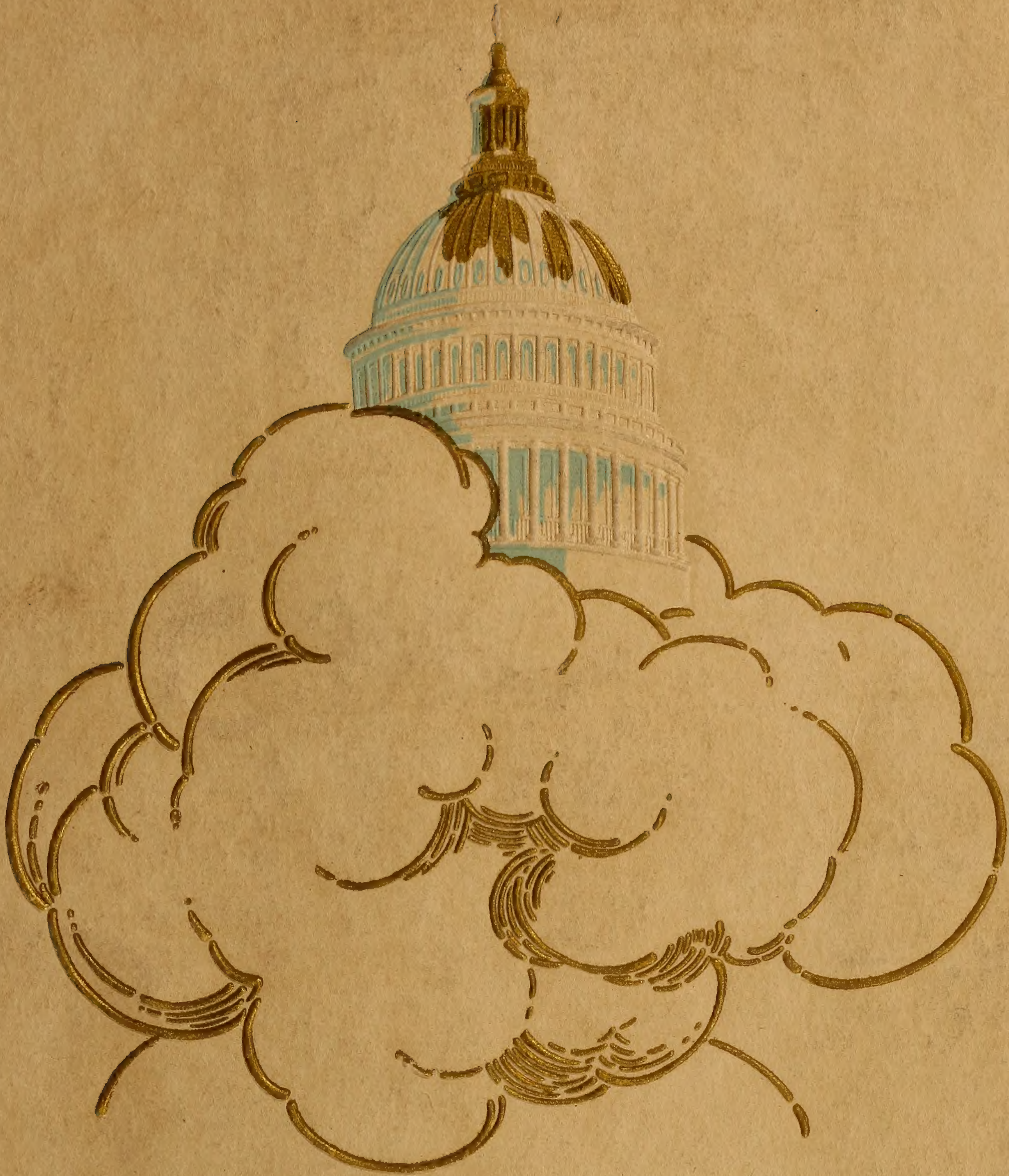

D.W. GRIFFITH'S

The Birth of a Nation

AUSPICES OF
MUTUAL FILM CORPORATION
H. E. AITKEN
PRESIDENT

SOUVENIR

THE BIRTH OF A NATION

The Most Stupendous and Fascinating
Motion Picture Drama Created
in the United States

Founded on Thomas Dixon's Story
"THE CLANSMAN"

PRODUCED UNDER THE PERSONAL DIRECTION OF
D. W. GRIFFITH

Scenario by D. W. GRIFFITH and FRANK E. WOODS
Music by JOSEPH CARL BREIL
Photography by G. W. BITZER

AUSPICES OF
THE MUTUAL FILM CORPORATION
H. E. AITKEN, President

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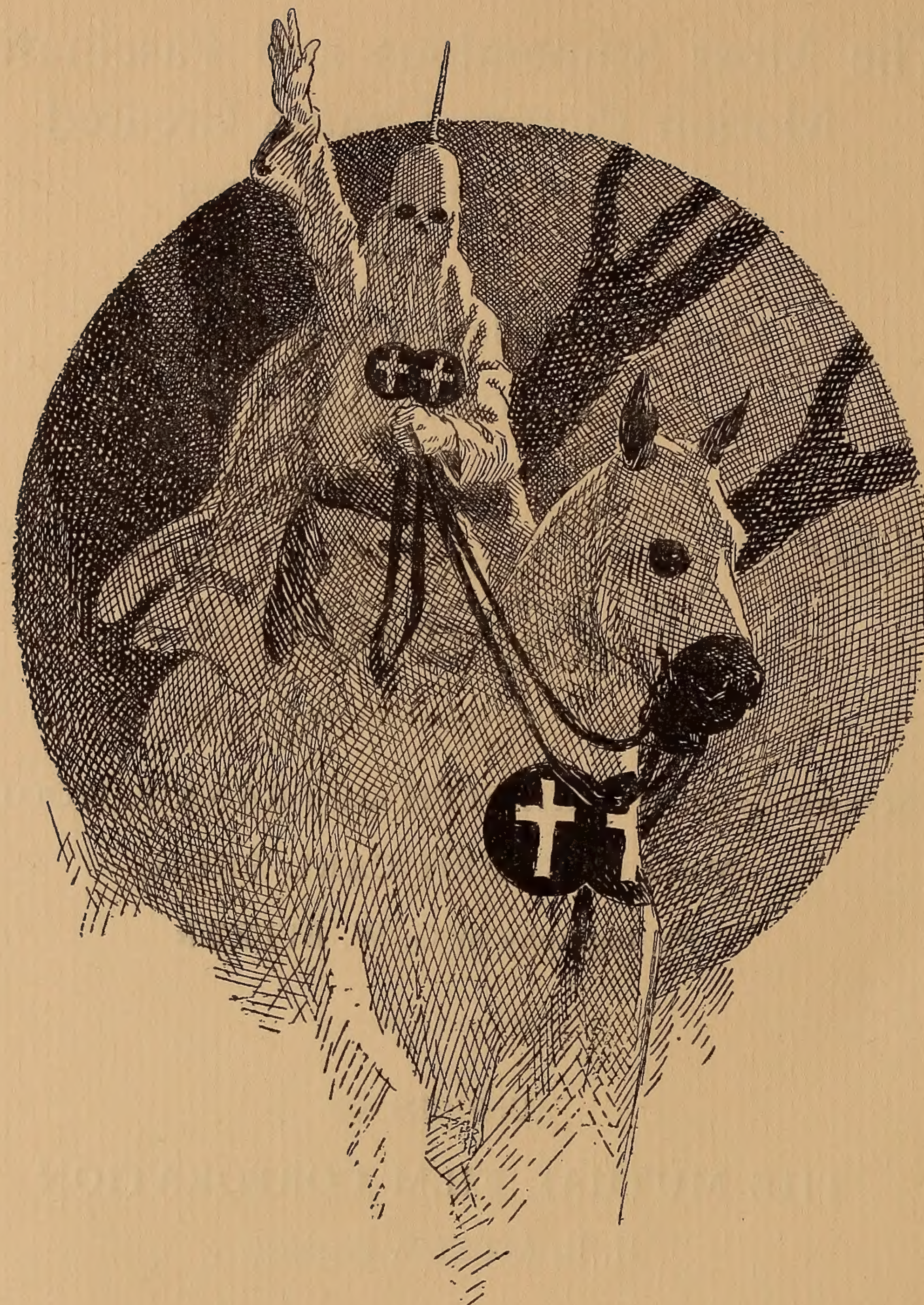


David Wark Griffith

"The most beautiful picture ever put on canvas, the finest statue ever carved, is a ridiculous caricature of real life compared with the flickering shadow of a tattered film in a backwoods nickelodeon."

THE above assertion was made by Dr. E. E. Slosson, of Columbia University in an article entitled "The Birth of a New Art" which was published in the Independent of April 6th, 1914.

On April 1st, 1914, David Wark Griffith, the subject of this sketch, set to work laying the ground plans for a great picture which has since been introduced to the world under the name "The Birth of a Nation."

Neither Dr. Slosson nor Mr. Griffith knew of the other's mental processes. While one was proclaiming the dawn of a new era the other was at work upon the long looked-for American play. It is rare to find prophesy and fulfillment so closely linked together.

No discussion of the relationship of motion picture art to contemporary life can be complete without a knowledge of what D. W. Griffith has done to develop and enlarge the artistic standards of motion photography. There is in his work a distinctive touch of individual craftsmanship; an all embracing attention to detail which has come to be known as the Griffith art.

No form of expression seeking to reveal the truths and beauties of life has ever made such progress within a given lapse of time as motion photography. Perhaps this is because motion is the essence of realism and life itself is but a part of the impulse of the universe, motion.

In developing the dramatic possibilities of the screen dramas Griffith has shown that he is not only a poet. He is a master technician. His accomplishments are the major part of the history of motion pictures in America. He is the creator of practically every photographic and dramatic effect seen today. He is responsible for nearly every innovation of the past decade. He was the first producer to bring rhythm and perspective into motion pictures and make them the background of his story.

Griffith's poetic imagination stretches across dreamy dales, through swaying trees, back to distant mountains with their snow crested tops blazing in the sunlight, it reaches across the lapping waves of a deep blue sea to what seems the end of the universe. From one of these far away vistas he brings forth a young girl and shows her progress until she comes so close you see a tear drop quiver on her eyelid before it falls to her cheek. This you see so clearly that through her eyes you read her innermost emotions. It seems almost too intimate, too realistic.

And then in a flash you see great plains and on them nations grappling in their death throes and worlds battling for military supremacy. Such sequences and multiplicities of action appear quite simple now, yet they had to be carefully thought out. We say with pride that an American invented the technique required to produce them.

When Griffith began directing picture plays the idea of showing human beings otherwise than full length was regarded as rank heresy. He created the "close up."

When he first photographed the faces of his actors, withholding everything not essential to the needed effect, audiences that now applaud, showed their disapproval by stamping their feet upon the floor. Critics said his characters did not walk into the pictures, but swam in without legs or arms. He next conceived the idea of the "switch back." By this device he shows a character under certain circumstances and the next instant by switching the action back to something seen before he makes you see what the character is thinking of. An improvement upon the original idea he accomplished by the slow fading in and out of mystical or symbolic figures which make you see what other characters are thinking of, thus avoiding the harsh jumping from one scene to another which had been the rule before.

While Griffith was making these mechanical improvements he was keenly alive to the needs of improved screen acting. No ten other men in America have developed so many film favorites. He is a born director of people, and can discover latent talent in a camera recruit quicker than any other man in the world. He loves to work with raw material and see a young player blossom into the full power of poetic expression. His aim has been to produce natural acting. The old jumpy-see-sawing of the arms and pawing of the air, mis-named pantomime, has disappeared under his watchful care. In less than six years Griffith has made screen acting a formidable rival of that seen on the legitimate stage.

These developments are but details of the forward movement of the art of motion photography. The old stilted forms have passed. The motion picture artist must henceforth be capable of taking infinite pains. He must have the poetic imagination and the technique to give expression to his dreams. With these requisites he becomes the super-artist of the new movement. This is Griffith, whose vision leaps to the furtherest ends of the world of fancy—pausing here to note the smile in the eyes of Youth; then to see the shadow of sinister crime fall across the vision of unsuspecting Purity; picturing now a tear on a child's cheek; now a nation in the throes of war, while roses bloom and pastoral scenes, such as Corot never dreamed of reproducing, form the background. These are the things that Griffith's art shows as no drama of the spoken word could hope to do. A new epic force illuminates human vision and human figures alive with the instincts and purposes of life obey the will of the super-artist.

This pioneer who has done so much to show the possibilities of this new art is unresponsive when it comes to his personal life. He thinks only of his work. He holds that people are interested in the deeds that men do, rather than in who the men are. We asked Mr. Griffith for a biographical sketch. He answered that he was born in Kentucky, that he grew up in a house like most boys; started out after his school and college days to find his place in the world, and that since he went into the business of producing pictures he has lived most of the time under his hat.


Mae Marsh
as
Flora Cameron
Lillian Gish
as
Elsie Stoneman
Miriam Cooper
as
Margaret Cameron
Henry Walthall
as
Col. Ben Cameron
Ralph Lewis
as
Austin Stoneman

A TRIBUTE TO

"THE BIRTH OF A NATION"

BY

RUPERT HUGHES

WHEN a great achievement of human genius is put before us, we can become partners in it in a way by applauding it with something of the enthusiasm that went into its making. It is that sort of collaboration that I am impelled to attempt in what follows.

When I saw "The Birth of a Nation" the first time, I was so overwhelmed by the immensity of it that I said:

"It makes the most spectacular production of drama look like the work of village amateurs. It reduces to childishness the biggest things the theatre can do."

For here were hundreds of scenes in place of four or five; thousands of actors in place of a score; armies in landscape instead of squads of supers jostling on a platform among canvas screens. Here was the evolution of a people, the living chronicle of a conflict of statesmen, a civil war, a racial problem rising gradually to a puzzle yet unsolved. Here were social pictures without number, short stories, adventures, romances, tragedies, farces, domestic comedies. Here was a whole art gallery of scenery, of humanity, of still life and life in wildest career. Here were portraits of things, of furniture, of streets, homes, wildernesses; pictures of conventions, cabinets, senates, mobs, armies; pictures of family life, of festivals and funerals, ballrooms and battlefields, hospitals and flower-gardens, hypocrisy and passion, ecstasy and pathos, pride and humiliation, rapture and jealousy, flirtation and anguish, devotion and treachery, self-sacrifice and tyranny. Here were the Southrons in their wealth, with their luxury at home, their wind-swept cotton fields: here was the ballroom with the seethe of dancers, here were the soldiers riding away to war, and the soldiers trudging home defeated with poverty ahead of them and new and ghastly difficulties arising on every hand.

Here was the epic of a proud brave people beaten into the dust and refusing to stay there.

The pictures shifted with unending variety from huge canvasses to exquisite miniatures. Now it was a little group of refugees cowering in the ruins of a home. A shift of the camera and we were looking past them into a great valley with an army fighting its way through.

One moment we saw Abraham Lincoln brooding over his Emancipation Proclamation; another, and he was yielding to a mother's tears; later we were in the crowded theatre watching the assassin making his way to and from his awful deed.

The leagues of film uncoiled and poured forth beauty of scene, and face and expression, beauty of fabric and attitude and motion.

"The Birth of a Nation" is a choral symphony of light, light in all its magic; the sun flashing through a bit of blown black lace and giving immortal beauty to its pattern; or quivering in a pair of eyes, or on a snow-drift of bridal veil, or on a moonlit brook or a mountain side. Superb horses were shown plunging and rearing or galloping with a

heart-quickening glory of speed down road and lane and through flying waters. Now came the thrill of a charge, or of a plunging steed caught back on its haunches in a sudden arrest. Now followed the terror of a bestial mob, the hurrah of a rescue, streets filled with panic and with carnival. Life is motion and here was the beautiful moving monument of motion.

"What could the stage give to rival all this?" I thought. "What could the novel give? or the epic poem?" The stage can publish the voice and the actual flesh; yet from the film these faces were eloquent enough without speech. And after all when we see people we are merely receiving in our eyes the light that beats back from their surfaces; we are seeing merely photographs and moving pictures.

I had witnessed numberless photoplays unrolled, pictures of every sort and condition of interest and value. I had seen elaborate "feature-films" occupying much time and covering many scenes. But none of them approached the unbroken fascination of "The Birth of a Nation."

The realism of this work is amazing; merely sit at a window and actually rolls by. The grandeur of mass and the minuteness of detail are unequalled in my experience. And so the first impression of my first view of this was that it was something new and wonderful in dramatic composition and in artistic achievement.

In his novel "The Clansman," the Rev. Thomas Dixon had made a fervid defence of his people from the harsh judgments and condemnations of unsympathetic historians. With this book as a foundation, David W. Griffith built up a structure of national scope and of heroic proportions.

Of course, size has little to do with art. A perfect statuette like one of the exquisite figurines of Tanagra is as great in a sense as the cathedral of Rheims. A flawless sonnet of Milton's need not yield place to his "Paradise Lost." A short story of Poe's has nothing to fear from a cycle of Dumas novels, nor has "The Suwanee River" anything to fear from the Wagnerian tetralogy.

And yet we cannot but feel that a higher power has created the larger work, since the larger work includes the problems of the smaller; and countless others. The larger work compels and tests the tremendous gifts of organization, co-ordination, selection, discipline, climax.

One comes from this film saying: "I have done the South a cruel injustice, they are all dead, these cruelly tried people, but I feel now that I know them as they were; not as they ought to have been or might have been, but as they were; as I should probably have been in their place. I have seen them in their homes, in their pride and their glory and I have seen what they went back to. I understand them better."

And after all what more vital mission has narrative and dramatic art than to make us understand one another better?

Hardly anybody can be found today who is not glad that Slavery was wrenched out of our national life, but it is not well to forget how and why it was defended, and by whom; what it cost to tear it loose, or what suffering and bewilderment were left with the bleeding wounds. The North was not altogether blameless for the existence of slavery, nor was the South altogether blameworthy for it or for its aftermath. "The Birth of a Nation" is a peculiarly human presentation of a vast racial tragedy.

There has been some hostility to the picture on account of an alleged injustice to the negroes. I have not felt it; and I am one who cherishes a great affection and a profound admiration for the negro. He is enveloped in one of the most cruel and insoluble

FORD'S THEATRE, WASHINGTON, D. C., APRIL 14, 1865
--ABRAHAM LINCOLN, OUR FIRST MARTYRED PRESIDENT

riddles of history. His position is the more difficult since those who most ardently endeavor to relieve him of his burdens are peculiarly apt to increase them.

"The Birth of a Nation" presents many lovable negroes who win hearty applause from the audiences. It presents also some exceedingly hateful negroes. But American history has the same fault and there are bad whites also in this film as well as virtuous.

It is hard to see how such a drama could be composed without the struggle of evil against good. Furthermore, it is to the advantage of the negro of today to know how some of his ancestors misbehaved and why the prejudices in his path have grown there. Surely no friend of his is to be turned into an enemy by this film, and no enemy more deeply embittered.

"The Birth of a Nation" is a chronicle of human passion. It is true to fact and thoroughly documented. It is in no sense an appeal to lynch-law. The suppression of it would be a dangerous precedent in American dramatic art.

If the authors are never to make use of plots which might offend certain sects, sections, professions, trades, races or political parties, then creative art is indeed in a sad plight.

"Uncle Tom's Cabin" has had a long and influential career. Perhaps no book ever written exerted such an effect on history. It was denounced with fury by the South as a viciously unfair picture. It certainly stirred up feeling, and did more than perhaps any other document to create and set in motion the invasion and destruction of the southern aristocracy. Yet it was not suppressed because of its riot-provoking tendencies. And it is well that it was not suppressed.

"The Birth of a Nation" has no such purpose. It is a picture of a former time. All its phases are over and done, and most of the people of its time are in their graves. But it is a brilliant, vivid, thrilling masterpiece of historical fiction. Thwarting its prosperity would be a crime against creative art and a menace to its freedom. The suppression of such fictional works has always been one of the chief instruments of tyranny and one of the chief dangers of equality.

I saw the play first in a small projecting room with only half a dozen spectators present. We sat mute and spellbound for three hours. When I learned that it had to be materially condensed it seemed a pity to destroy one moment of it. The next time I saw it was in a crowded theatre and it was accompanied by an almost incessant murmur of approval and comment, roars of laughter, gasps of anxiety and outbursts of applause. It was not silent drama so far as the audience was concerned.

The scene changed with the velocity of lightning, of thought. One moment we saw a vast battlefield with the enemies like midgets in the big world, the next we saw some small group filling the whole space with its personal drama; then just one or two faces big with emotion. And always a story was being told with every device of suspense, preparation, relief, development, and crisis.

I cannot imagine a human emotion that is not included somewhere in this story from the biggest national psychology to the littlest whim of a petulant girl; from the lowest depths of ruthless villainy to the utmost grandeur of patriotic ideal.

All of the seven wonders of the world were big things. I feel that David W. Griffith has done a big thing and he has a right to the garlands as well as the other emoluments. "The Birth of a Nation" is a work of epochal importance in a large and fruitful field of social endeavor. In paying it this tribute of profound homage, I feel that I am doing only my duty byAmerican art, merely rendering unto Caesar the things that are Caesar's.

A NATION IS BORN

AMONG our fathers lived a poet-leader who dreamed a new vision of humanity—that out of the conflicting interests and character of thirteen American States, stretching their territories from the frosts of the north to the tropic jungles of Florida, there could be built one mighty people. For eighty years this vision remained a dream—sectionalism and disunity the grimmest realities of our life.

Lord Cornwallis, the British Commander, had surrendered at Yorktown, Virginia to the allied armies of the Kingdom of France and the original thirteen States by name—New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Virginia, Maryland, North Carolina, South Carolina, and Georgia. Through seventy-five years of growth and conflict these States clung to their individual sovereignty, feeling with jealous alarm the slow but resistless growth of a national spirit within the body of the Federal Union. This new being was stirred at last into conscious life by Daniel Webster's immortal words—

"LIBERTY AND UNION,
ONE AND INSEPARABLE,
NOW AND FOREVER!"

The issue, which our fathers had not dared to face—whether the State or the Union should ultimately have supreme rule—was joined in 1861 over the problem of the Negro.

The South held with passionate conviction that we were a Republic of Republics, each State free and sovereign. The North, under the leadership of Abraham Lincoln, held that the Union was indestructible and its sovereignty supreme.

Until Lincoln's day the right of each State to peaceful secession was scarcely disputed, North or South. New England had more than once threatened to withdraw long before South Carolina in her blind rage led the way.

And yet, unconsciously, the new being within had grown into a living soul, and, in the mortal agony of four years of Civil War and eight years of more horrible Reconstruction, a Nation was born.

THOMAS DIXON.

GEN. ROBT. E. LEE'S LAST STAND ON THE

AMOUS BATTLEFIELD OF PETERSBURG, VA.

THE STORY OF THE PICTURE

THE FIRST ship that brought a cargo of African slaves to North America started the series of troublous events preceding the birth of a great nation. Abolition was subsequently advocated, but the idea of social equality was never considered. The South declared it would secede, if in 1860 a Republican president was elected. That president, Abraham Lincoln, issued a call for 75,000 volunteers. For the first time in American annals he used the Federal power to subdue the sovereignty of individual States.

The Stoneman boys of Pennsylvania had been house guests at Piedmont, S. C., of their boarding-school chums, the Cameron boys. Phil Stoneman and Margaret Cameron, "fair as a flower," had looked, longed and loved. Ben Cameron had never met Elsie Stoneman, yet the daguerreotype of her he had pilfered from Phil seemed about the dearest, sweetest thing in the world. The younger lads of the two houses—too young for sentiment and romance—frolicked like friendly young colts. Most charming and lovable of all the Cameron clan was the Doctor and Mrs. Cameron's youngest daughter Flora.

When War casts its shadow over the land, Phil and Tod Stoneman are summoned to fight for the Stars and Stripes; Ben Cameron and his two younger brothers, for the Stars and Bars. The grim years drag along. Piedmont gayly enters the conflict, but ruin and devastation follow. The town gets a foretaste of rapine and pillage in the raid of a mixed body of white and colored guerillas against it. The scale of events inclines to the Union cause. Southern wealth and resources are burned or commandeered by Sherman in his march to the sea. Meantime two of the Cameron boys have perished in battle, one of them face to face with his dying chum Tod. Grant is pressing the Confederacy in the famous campaign around Petersburg. When Confederate supplies are running low, one of their provision trains is cut off and the "little Colonel," Ben Cameron, is called upon by Gen. Lee to lead a counter attack and thus, by diverting the enemy, aid in the rescue of the train. We see the panorama of a battlefield flung over many miles of mountain and valley, the opposing intrenchments and the artillery fire, Col. Cameron and his men forming for the advance, their charge over broken ground, the grim harvest of death that swept most of them away, the bayonet rush of the devoted few right up to the trenches, the physical hand-grapple with the enemy, and Cameron,

sole survivor, gaining the crest of the Federal works and falling wounded into the arms of Capt. Phil Stoneman, U. S. A., his erstwhile bosom friend. Prisoner in a Washington hospital, Ben Cameron slowly recovers from his wound. Like an angel of mercy Elsie Stoneman, Phil's sister, appears in the role of a volunteer nurse. Poor Ben falls desperately in love with her whose picture he had carried about for years. She and Ben's mother visit Lincoln, "the Great Heart," who clears the "little Colonel" of an odious charge and hands Mrs. Cameron the boy's papers of release.

It seemed to Austin Stoneman, leader of Congress and Elsie's parent, that Lincoln was pursuing too mild a policy with the prostrate South. "I shall treat them as if they had never been away " was Lincoln's gentle answer to Stoneman's demand that the leaders be hanged and measures of reprisal adopted. What was there in Stoneman's life that made him so bitter to the Southern whites? Stoneman purposed to establish the complete political and social equality of the negroes. He was grooming a half-breed protege, one Silas Lynch, to go South as the "leader of his people."

The War ends in 1865 with the encirclement of the Southern army and the surrender of Robert E. Lee to U. S. Grant in the historic house at Appomattox Courthouse. There follows a terrible tragedy—the assassination of President Lincoln by Wilkes Booth in the crowded scene of a festival performance at Ford's Theatre on April 14, 1865. The South feels—and feels truly—that it has lost its best friend.

A few years later comes the real aftermath. Austin Stoneman, now supreme through the Congressional power of over-riding President Johnson's veto, goes south to supervise his "equality" programme. Elsie accompanies him, and so does Phil. They arrive in Piedmont and take a house next door to the Camerons. Elsie accepts the gallant little Confederate colonel, Ben Cameron, but the shadows of war-time hang too heavily over Margaret Cameron to permit her to make up at once with Phil. Meanwhile the reign of the carpet-baggers begins. The "Union League," so-called, wins the ensuing State election. Silas Lynch, the mulatto, is chosen Lieutenant-Governor. A legislature, with carpet-bag and negro members in overwhelming majority, loots the State. Lawlessness runs riot. Whites are elbowed off the streets, overawed at the polls, and often despoiled of their possessions. Ben Cameron then leads the white men of the country in organizing the "invisible empire" of the Ku Klux Klan. Devoted women of the South make the white, ghost-like costumes behind locked doors. Austin Stoneman boils with rage over this newest development. Lynch's spies bring evidence that the garments are being made by the Camerons and that Ben Cameron is night-riding. Stoneman bids Elsie to disavow her "traitorous" lover, and she, astonished and wounded that Ben is engaged in such work, gives him back his troth.

Little Flora Cameron, the joy and pride of the Cameron household, was sought after by the renegade family servant Gus, who had become a militiaman and joined Lynch's crew. Often had Flora been warned by her brother and parents never to go alone to the spring in the woods hard by the cliff called Lover's Leap. Little heeding the admonition, she took her pail one day and started off. Gus the renegade followed. Frightened by his approach, the little girl broke into a run. Gus ran too. Colonel Cameron, learning that she had gone alone, hastened forth and was the third person in the chase. Desperately the little girl zigzagged this way and that, dodging the burly pursuer, then, almost cornered, she climbed to the jutting edge of Lover's Leap whence, as Gus approached nearer, she leaped to her death. Brother Ben discovered the poor dying girl a few minutes later. Gus escaped, but he was afterwards captured, tried and

THE COMING OF BROTHERLY LOVE INTO THE HALLS OF PEACE

found guilty. Then the Ku Klux Klan sent a messenger to the Titan of the adjoining county asking for re-inforcements to overawe the carpet-baggers and negroes.

The next outrage upon the unhappy family was the arrest of Dr. Cameron for having harbored the clansmen. As the soldiers were parading him to jail, Phil Stoneman, now a warm sympathizer with the southerons, and some others organized a rescue party. They beat down the militia; the Doctor and his wife, Margaret, Phil and the faithful servants fled out into the country where they found refuge and warm hospitality in the log cabin of two Union veterans. The cabin was fortified and preparations were made against the militia's attack.

We must now leave the handful of whites defending the log cabin from the militia-men and visit Lieutenant-Governor Lynch's mansion in Piedmont. Miss Elsie Stone-man is there on the errand of appealing to Lynch, the "friend" of her father in behalf of her brother and the Camerons. But instead Lynch siezes this opportunity to declare his "love" for his patron's beautiful daughter, says he will make her queen of his empire, and orders a negro chaplin to be sent for to perform a forced marriage. At this crucial moment, word is received of Congressman Stoneman's return. Lynch goes out to tell him that he (Lynch) aspires to the hand of the white man's daughter. Then Stoneman, the "social equalizer," the theoretical upholder of the intermarriage of blacks and whites, finds all his theories upset by the personal fact. Rage and storm as he will, Stoneman too is helpless. There is but one hope anywhere in prospect—the courageous and chi-valric host of Ku Klux riding for dear life towards Piedmont.

Ben Cameron, the "little Colonel", is at their head. They are armed to the teeth and pledged to victory or death. As they rush the little mountain town, their guns mow down the militia troops opposing them; the Lynch mansion is taken, and Ben and his men bursting into the room free the Stonemans, Ben taking the overjoyed Elsie in his arms. But there is other work afoot. Quickly a detachment of the clansmen remount and hurry to the scene of the attack of the cabin. The little party within its besieged walls are almost at the last gasp. The militia raiders are forcing the doors, already half a dozen of them have gained the inside of the cabin, when the crack! crack! crack! of the Ku Klux rifles announce rescue and safety. The surprise attack routs the raiders completely, and the men and women of the party hug and kiss their deliverers.

There is little left to tell. To Ben and Elsie, to Phil and Margaret, the sequel is a beautiful double honeymoon by the sea. To the American people, the outcome of four years of fratricidal strife, the nightmare of Reconstruction, and the establishment of the South in its rightful place, is the birth of a new nation. Lincoln's plan of restoring the negroes to Africa was dreamed of only, never carried out. The new nation, the real United States, as the years glided by, turned away forever from the blood-lust of War and anticipated with hope the world-millenium in which a brotherhood of love should bind all the nations together.

A New Art Recognized

IT WAS a radical departure to bring a motion picture play into one of the best known theatres in New York City and offer it at the standard scale of prices charged for the established dramas of the season. This move was not more unusual than the reception accorded the production by the foremost reviewers on the metropolitan newspapers. All the professional critics in New York saw the opening performance and their reviews were extremely enthusiastic. Without a dissenting voice the picture was proclaimed the sensation of the season. Many critics admitted that it was the first time they had ever reviewed a motion picture play. Their endorsement was but a repetition of the praise that has been bestowed upon this wonderful work by men in every walk of life. Jurists, Senators and Congressmen, artists, writers, illustrators and men of every profession have seen it and pronounced it the apotheosis of the moving pictures. The following excerpts from the criticisms of the best known reviewers in New York will give the reader a thorough idea of the enthusiasm the presentation aroused:

From New York American

"Birth of a Nation" True and Wonderful

By REV. THOMAS B. GREGORY.

In the great photo spectacle, The Birth of a Nation, which had its initial presentation at the Liberty Theatre Wednesday evening, Mr. Griffith comes pretty near working a miracle.

And yet this is just what Mr. Griffith has done, and done with a completeness and perfection that is astounding.

As a picture play The Birth of a Nation is by all odds the greatest thing that has ever come to New York, and in this masterpiece of motion picture production we may see something of the possibilities of the art as an educator of the human race, through the most royal of the senses, the eye.

WAVES A MAGICIAN'S WAND.

Seeing is believing—and in this wonderful photo play we actually see the birth, growth and coronation of this King of Nations, this giant of the Powers of the earth—a people compared with whom the Romans were but as pygmies.

As if by the waving of some magician's wand the great scenes are, one after another, unrolled before us.

Mr. Griffith and his forces were eight months making the picture. They traveled over the sections in which the story is located, and reproduced the scenes with rigid fidelity. Thousands of works of historical and official value

SHERMAN'S MARCH TO THE SEA—REFUGEES FLEEING FROM ATLANTA

were carefully read to get at the full and exact particulars. It is no wonder, in the light of these facts, that the making of the great picture involved the expenditure of more thau $350,000.

TRUTH IN EVERY LINE.

And it is well worth all that it has cost. As an educator its value is well nigh inconceivable, and its chief value in this direction lies in its truthfulness. That the story as told by the pictures is true I am ready to swear on the Bible.

I know it is true, because I lived through the actual realities themselves. I saw the real carpet-baggers, the real "New Voters," the real reconstruction "Statesmen," the real Ku-Klux Klanners. I knew the real Stoneman, the real Lynch, the real Camerons, and was a living part of the stupendous tragedy, watching it with wondering eyes and bated breath from its inception under the Stonemans and Lynches to its cessation under the invisible blows of the Ku-Klux Klan.

I am prepared to say that not one of the more than five thousand pictures that go to make up the wonderful drama is in any essential way an exaggeration. They are one and all faithful to historic fact, so that looking upon them, you may feel that you are beholding that which actually happened.

Regarding the educational value of the great photo play, no one who sees it can be the least bit sceptical.

It is a spectacle that makes you think and feel.

If you want to realize how closely and how rigidly the connection is between wrong and its punishment, then see the play.

From NEW YORK JOURNAL

The "Birth of a Nation" Film Masterwork

By DOROTHY DIX.

I am a Film Fan, but I never had the slightest conception of what could be done with the moving picture as an art until I saw The Birth of a Nation at the Liberty Theatre at its initial production in New York.

I had considered the moving picture interesting, instructive, amusing, diverting, beautiful, spectacular, but I had believed that the silent drama never could touch the emotions very deeply. I had thought that to grip an audience, to melt it to tears with pathos, to thrill it with high heroic sentiment, required the spoken word and the magic of the human voice.

The Birth of a Nation disproves all of this theory. Here is a war play, the like of which never has been presented on any stage before, that played upon the heart as upon a harp of a thousand strings; that worked the audience up into a perfect frenzy; that mingled pathos and humor, tragedy and glory; at which people wept and laughed, and yet not one word was spoken on the stage.

The whole thing was fascinating, yes, terrible beyond belief, because you saw, as the angels looking down from heaven must have seen, all of the causes that lead to the Civil War, the bloody struggle in which brother fought brother, and the ghastly aftermath of the conflict.

HISTORY BY LIGHTNING.

There have been many war plays, but none comparable to this, for none have had its scope. The eye is swifter than the ear. You can see in an instant the whole of a situation that it would take any one an hour to describe to you,

and so it has been possible to compass in this moving picture drama the whole story of the Civil War instead of giving just an episode to which any spoken drama must needs confine itself.

The Birth of a Nation is founded on Thomas Dixon's novel, "The Clansman," but it is as much more vital than the book as the thing we see is to the mere printed words telling it.

A NEW ART IS BORN.

The Birth of a Nation is the apotheosis of the moving picture. Thousands of people took part in making it. The scenes where real battles were fought are its background. In it you see the counterfeit presentment of the great men of the Civil War as they were when they lived and moved and had their being—Lincoln, the great heart of that troublous time; Grant, the magnanimous; Lee, the Bayard of the South; Charles Sumner, aristocrat to his finger tips; Seward, cold and cruel and hard as death, and a dozen others who made history.

The Birth of a Nation is history vitalized and made living. Go and see it for that. Go and see it because of the wonder of the pictures themselves, and the marvel of this new art of film making, of which it is the last word.

And finally go and see it because it will make a better American of you, for out of the baptism of blood of the Civil War was born the new nation, one and indivisible.

From LIFE

By JAMES S. METCALFE.

The Birth of a Nation is the biggest attraction of the season. Its drama is so intense that it brings the audiences to their feet as no theatrical play has in many, many years. It is asking and getting regular theatrical prices—$2 orchestra chairs and other seats on the same basis. The Liberty Theatre is twice daily holding bigger audiences than ever before in its history.

The Birth of a Nation seems to have been produced by a genius to interest all kinds and conditions of Americans.

From NEW YORK EVENING MAIL

By BURNS MANTLE.

The mind falters and the typewriter balks before an attempt to either measure or describe D. W. Griffith's crowning achievement in screen drama, The Birth of a Nation. . . . The pictures are wonderful, and there is an element of excitement that last night swept a sophisticated audience like a prairie fire.

From NEW YORK WORLD

By LOUIS DEFOE.

Birth of a Nation in wonder pictures. Motion photography at its best in screen version of The Clansman at the Liberty. The audience, which closely resembled the first night gathering of one of the important dramatic events of the season, surrendered completely to the emotional appeal. . . . . As the pictures were unreeled they sat in subdued silence, but when the tension ended broke forth in prolonged applause in recognition of the pictures' uncanny realism.

WAR'S PEACE

From New York Press

By HAMILTON OWEN.

Makes profound impression. Acting is excellent. The death of President Lincoln, which brings the first act to a close, shows some extraordinary pictures of the interior of Ford's Theatre, the movements of the actors on the stage, of the throng comprising the audience, suggesting nothing but the great tragedy itself, with never a blur of artificiality anywhere in the pictures.

From New York Tribune

By HECTOR TURNBULL.

The spectacle will win popularity because of its tremendous thrilling war scenes, and the following exciting raids of the Ku-Klux Klan.

From Evening Globe

By LOUIS SHERWIN.

Here is beyond question the most extraordinary picture that has been made—or seen—in America so far. It is bewildering to think of the elaborate organization, the number of people and the amount of equipment it required to put this drama on the screen.

From New York Times

The Civil War battle pictures represent enormous effort and achieve a striking degree of success.

From New York Sun

By LAWRENCE REAMER.

This film spectacle is the greatest and largest ever produced. A drama of human conflicts links history to romance.

From Dramatic Reviewer for the Columbiad

By REV. FATHER JOHN TALBOT SMITH.

The Birth of a Nation is a very noble and splendid picture. As a representation of history it is one of the greatest that has ever been presented to the world, for in the short space of three hours the audience sees, hears and feels a period of fifteen years.

From New York Herald

The Birth of a Nation, the two dollar motion picture, more than fulfilled its promise. *A new epoch in the art is reached.* The play is a big step forward.

From Evening World

By CHARLES DARNTON.

The Birth of a Nation is big and fine. The charging of the trenches with hand-to-hand fighting is a scene that has a deadly fascination, while the tremendous artillery duel leaves little to the imagination.

From NEW YORK EVENING JOURNAL

By C. F. ZITTEL.

It's worth $5.00 *a seat to see The Birth of a Nation.* First of all, children must be sent to see this masterpiece. Any parent who neglects this advice is committing an educational offense, for no film ever produced has more educational points than Griffith's latest achievement. . . . . The Birth of a Nation will thrill you, startle you, make you hold on to your seats. It will make you laugh. It will make you cry. It will make you angry. It will make you glad. It will make you hate. It will make you love. It is not only worth riding miles to see, but it is worth walking miles to see.

From NEW YORK TELEGRAPH

A picture play par excellence. Premier of The Birth of a Nation at the Liberty Theatre an unqualified success. Audience literally thrilled. Production stupendous in scope and gorgeously prodigal in detail.

From EVENING SUN

By ERROL HART.

The Birth of a Nation marks a new epoch. Powerful photo play sweeps the crowd off its feet. *Never before has such a whirlwind combination of story, spectacle and tense drama been unrolled before New Yorkers.*

From NEW YORK NEWS

The true greatness of this production lies in its emotional appeal, an appeal so forceful that it lifts you out of your seat and thrills you as the speaking stage never did and never will. Historically it is magnificent; a great, true artistic photograph of the crisis of a great war. Never before, on canvas, by photography, or by literature has the great grapple of the Civil War been so graphically visualized.

From NEW YORK JOURNAL OF COMMERCE

As pictures of history in the making, The Birth of a Nation is of great value to old and young. It places before the eyes of the present generation events of which they have only been able to read hitherto, and shows them in such a way that no spectator can fail to be impressed.

From NEW YORK COMMERCIAL

The Birth of a Nation is a wonder in pictures. There is action a-plenty and acting of a superior quality. A noticeably gratifying feature is the absence of over-acting on the part of the principals.

From NEW YORK AMERICAN

By MARGERY STOCKING.

The great scene of the perilous charge of the Clansman has been responsible for the restoration of the hero to Broadway. As it is enacted on the screen each night the spectators actually rise from their seats and burst into cheers. *The play furnishes the spectators with a thrill that has long been absent from Broadway.*

PROSPECTUS OF THE DAILY ILLUSTRATED

OPEN LETTER,

Published by OPEN LETTER PUBLISHING COMPANY, of San Francisco, California. Branch Office, 756 Washington Street, Boston, where all Letters should be Addressed in regard to this Publication.

Sent During Campaign, 50 Cents, in Advance. **BOSTON, MASS., SEPT. 20, 1878.** **Single Copies, 2 Cents.**

THE DEMOCRATIC CONVENTION.

AT WORCESTER.

When the great body of the delegates to the Democratic Convention, composed of a large per cent. of Workingmen revolting in spirit, if not in name, against the tyranny of a few of the blue bloods who sought to use them as in the past, they exhibited [illegible], and we approved of their action.

When they by strategy succeeded in forcing an entrance to the hall, in which, by the call, they were entitled to sit, and were plainly told they could not "as they were communists," and were hunted by the Mayor as a mob, they defied the Mayor and the State Central Committee, and cried Majority must Rule force or no force, we said Bravo!

When they went into convention and pitched the high-toned bulldozers overboard, and by their actions, if not in form the sickening name "Democratic Party" along with them, unanimously nominated a man for Governor, who had done the same thing with his party, our heart beat in unison with theirs.

But alas, the intoxication of success. At that moment, the Workingmen with joy illumining every feature, and with ecstatic hopes of future success and deliverance from thralldom, the wily, cold blooded political bummers were on hand, and instead of allowng the delegates to go on in the same Democratic manner, and choose the remainder of the state ticket, what did they do? By a cut and dried arrangement, a certain person was chosen permanent chairman, a political "bumming" office holder under the administration which he so vehemently condemns, a librarian of Congress, advanced hesitatingly (?) to the front and taking a manuscript from his side pocket, on which was written a flowing speech to catch flies, he lied to the people in the first words he uttered, he said that it was "unexpected, the honors conferred, ahem!"—and yet cooly laid down his manuscript bowed his head piece, worn bare, in studying ways to gull the workingmen in times past, and read off what he had prepared for the occasion Workingmen of the Democratic Convention, were you asleep, did you not notice it? Did you not notice from that time forth that you were captured? The political Delilah had found your lock of strength, "Butler." And they tack on to his tail, by "Committee" star chamber arrangement, a lot of political and other old barnacles, and in the excitement you endorsed them. Why did you not choose the remainder of your ticket by the voice of the people—of yourselves—when you nominated Butler. you did well, but then you should not have stopped. The only thing left for you to do now is to come and help pick out Workingmen, and place them on the greenback workingmen's ticket, with Butler at its head, whose legitimate candidates he is.

Consider this well, before voting for any of the names of the Worcester Democratic Convention. and be men—Free men.

THE OPEN LETTER.

Arrangements are being made by the illustrated OPEN LETTER Publishing Company of San Francisco,—the organ of the Workingmen's Party of California,—to publish a small illustrated daily in Boston, during the coming campaign, similar to the OPEN LETTER which made such a noble fight in the campaign there, and which, next to Denis Kearney, did more to win the great battle in California than any other cause. Its principle characteristic will be to lampoon the oppressors of labor with spirited cartoons, show up their thieving and rascalities so that he who runs may read or understand at a glance. Like Denis Kearney it will call things by their right names, without regard to maudlin false modesty, and utilize its small space with blows straight from its shoulder, to draw blood every time. No long-winded, tiresome, nonsensical lectures on what would be, if such and such were the case: but, will point out what must be to ameliorate the working classes,—elect Workingmen to office, and hold the Damocles blade of terrible retribution over their heads, if they fail in their duties. This number is the prospectus,—and will be followed in a short time by daily issues. It will be mailed daily during the campaign for fifty cents, single copies two cents. If you wish to subscribe send your address and money immediately so as to commence with the first number, which will contain a genuine portrait of Denis Kearney. President of the Workingmen's Party of California.

ILLUSTRATED DAILY OPEN LETTER PRICE 2 CENTS

TON SEPT 18, 1878 — 756 WASHINGTON ST.

DRAWN ON THE STONE BY CARL BROWN

THE OPEN LETTER.

THE PEOPLE'S
Nominations.

FOR GOVERNOR,

Benj. F. Butler.

PLATFORM OF THE MASSACHUSETTS GREENBACK PARTY.

Whereas, By the vicious and reckless administration of public affairs we have seen our prosperity blighted, our industries crippled, and our people reduced to want and misery; and whereas, the old political parties offer no relief, but are, on the contrary, responsible for this sad state of things, having legislated invariably in the interest of the few at the expense of the many and against the interest of land and labor, which are the sources of all wealth, we call upon the people to declare their independence from these false guides, and aid us in regaining the priceless rights bequeathed to us by our patriotic sires. To this end we invite the co-operation of every good citizen, and offer the following resolutions enunciatory of the principles of the National Greenback Labor Party of Massachusetts.

Resolved, That much of the present legislation and cost of Government is a huge swindle upon the industries of the country, procured and instituted by plunderers to fill their purses, and to provide pay for those who manipulate the people, pack the caucus and stuff the ballot boxes; and that just and equal laws, and honest and economical government must, can and shall be established.

Resolved, That as the important function of furnishing a money to the people belongs solely to the nation and should not be delegated to any power, private or corporate, therefore we demand that in the future the Government alone shall issue the money of the country, and that said money shall be a full legal tender for the payment of all debts, public and private, protected and received by the Government as absolute money and the volume thereof maintained at a fixed rate per capita by constitutional amendment, so that permanent justice may be done to all men by having general values remain the same.

Resolved, That we demand the immediate repeal of the resumption act, so that the periodical carnivals of bankruptcy may forever come to an end and that our national wealth be made the fixed and reliable foundation of our monetary system, forever banishing from American finance idiotic propositions of making commodities of shifting value and articles of merchandise, like gold and silver, a basis for money — a basis that ever has, as in 1837 and 1857, and ever must, periodically, slip out from under such a monetary system, thereby destroying it and plunging the country into ruin and bankruptcy; a basis that even England has never been able to maintain for any great length of time, although she is the creditor nation of the world.

Resolved, That the United States shall never issue any more interest-bearing bonds unless the same are authorized by a direct vote of the people, and those issued during the war of the Rebellion shall be paid as fast as they mature according to the terms of the contract which authorized and created that indebtedness of the people, and what that contract is shall be submitted to the decision of the Supreme Court of the United States; and that all subsequent acts which impair and change the original contract are hereby denounced as creatures of corruption and repudiation that must be repealed.

Resolved, That the Labor Bureau should be sustained, its field of operations enlarged, and its officers selected from those engaged in industrial pursuits and having the confidence of the industrial classes of the Commonwealth, for the purpose of obtaining reliable statistics to form a basis for intelligent legislation on labor questions, especially with regard to the hours of labor, which should be reduced in proportion as the use of machinery increases and in conformity with other causes which throw wage workers out of employment.

Resolved, That farming land of equal productive capacity shall be subject to equal taxation, whether cultivated or not, to the end that the land monopolist in the future may be held in check, and that the public domain may be preserved to the actual tiller of the soil.

Resolved, That the gigantic railroad monopolies must be broken up.

Resolved, That the liberties of this people imperatively demand that the far-reaching and deadly hand of capital as it appears in the infamous monopoly known as the Associated Press must be torn from the throat of public intelligence. The telegraph companies must be forced to sell the daily news upon equal terms to any paper desiring to purchase the same.

Resolved, That the payment of a poll tax as a condition of exercising the right of the ballot is a violation of democratic principles and tends to corrupt the legislator, and all such odious restrictions should be abolished.

Resolved, That no person should be taxed for that which he owes; in other words, for the purposes of taxation, all persons shall have the right to deduct from the value of their estates the sum of the mortgages thereon, and said mortgages should be assessed to the persons to whom they are due.

Resolved, That the system of letting out convict labor by contract is detrimental to the interests of the workingmen and should be abolished.

Resolved, That the public lands are the property of the people; therefore they should be reserved for actual settlers, aided to their settlement by Government, and protected in their possession by just laws.

All letters to Denis Kearney, should be addressed to the office of the Open Letter, 756 Washington St., Boston.

KEARNEY'S WELCOME TO NEW ENGLAND.

Thrice welcome Kearney! noble name
to our Puritan land,
We've longed to see thy manly form, and
grasp thy brawny hand,
We've longed to see thy sparkling eye,
lit up with freedoms flame
And hear thee bid the slave, Arise! in
God's and Freedom's name.

Too long have knaves with siren tongue,
the Son of Toil betrayed.
Too long are dupes in freemen's garb
'gainst freedom's truths arrayed
And long in discords ranks we've bled,
still plundered by the foe,
'Till Kearney charged his columns on,
and laid the tyrant low.

The hireling press, by fear inspired, are
foaming in dismay,
And, naught but envy's sneer is heard,
for him who left the "dray"
And ventured forth on stormy main, frail
Labors bark to save
Ere all went down in dark despair, neath
Greeds remorseless wave.

But marvel not why heathen band, pour
forth the vengeful spleen,
They heard the warning thunder's roll,
the lightening's flash was seen,
'Twas Kearney smote with magic wand,
and off the shackles rolled,
OPPRESSION trembled, Shylock shrieks,
"My Slaves! My Bonds! My Gold!"

Then Welcome! Welcome!! Tribune
brave, thy fame has filled the land,
We've longed to see thy manly form, and
clasp thy good right hand
With laurel wreaths thy brow we'll
twine, when freedom's fight is won,
And shout, "May long live Kearney!"
from noon 'till setting sun.

Robert Pyne.

— The excitement at Worcester was at fever heat half past 10, A. M.

— What are you laughing at? remember, "tall oaks from acorns grow."

— Millionaires, bank presidents, and political bummers are all dying or committing suicide in California, — President French Savings Bank the last. Next.

San Francisco Subcribers served by M. Shea, 825 Market St, or at Open Letter Office with Murphy & Co., successor to Cubery & Co 420 Market St upstairs.

— The workingmen of San Francisco pitched over their State Central Committee the same way, — the latter bolted and called themselves the "Regular" and polled 24 votes.

— Remember to send your order by Monday next, if you wish to get this little paper from the start. Address "Open Letter" 756 Washington St., Boston — enclose 50 cents for the campaign. Sent post paid.

Notes *and* Pictures *of* Boston

·Historic Shrines of·
Cambridge Lexington
Concord Salem Plymouth

Notes *and* Pictures *of* Boston

is intended as a souvenir for the visiting tourist. Many pictures have been taken in Boston but few of them have caught the quaint spirit which this collection portrays and which is ever present in the hearts and minds of those who know and love this historic community. The idea is to suggest something of the Boston spirit by a limited amount of text and a group of artistic photographs by The Maynards

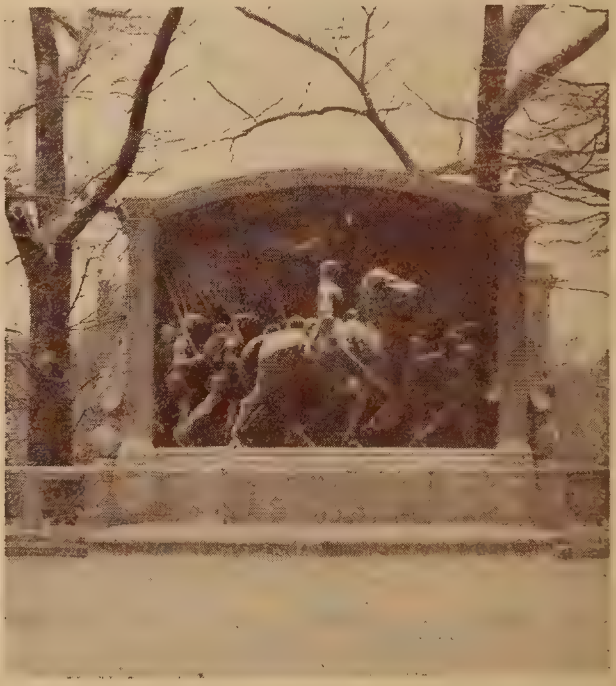
Compiled and Published by C. F. Smith, 520 Boylston Street, Boston, Mass.

Massachusetts State Capitol Building

The State House stands on Beacon Hill, the site of the home of John Hancock, facing the famous Boston Common. The corner-stone of the original Bulfinch front was laid July 4th, 1795 by Samuel Adams, Paul Revere reading the Masonic ceremony. An extension was built 1889. Construction of east and west wings completed 1916. Important things to see within the State House include historic paintings, battle flags and war relics. The House of Representatives contains the historic codfish. The Boston Common consists of about forty-eight acres, was purchased in 1634 by Governor Winthrop and others from William Blackstone who held it by right of possession granted prior to the establishment of Boston.

On Boston Common, crowning Flagstaff Hill where British Artillery was stationed during siege of Boston.

Soldiers and Sailors Monument



On Beacon Street opposite State House, erected in memory of Col. Robert Gould Shaw and the Fifty-fourth Mass. Designed by Agustus Saint-Gaudens.

Shaw Memorial

Boston Public Gardens and Swan Boat Pond

Twenty-four acres of flowers and shrubbery bounded by Charles, Arlington, Beacon and Boylston Streets. Separated from Boston Common by Charles Street. Originally a part of the Charles River Marshes, now a part of the famous Back Bay section which is all made land. The Boston Public Gardens are considered one of the beauty spots of the world. In the centre is an artificial pond where the children spend many delightful hours in the city swan boats during the summer, and skating during the winter. In the gardens are memorials to many famous sons of Massachusetts.

A riot between the townspeople and the British Red Coats, March 5th, 1770, when five Americans were killed was known as the Boston Massacre. This monument commemorating the event stands on Boston Common.

Washington Monument

In the Public Gardens facing Commonwealth Avenue is the George Washington Memorial of Boston. The spire is the Arlington Street Church made famous by William Ellory-Channing.

Boston Massacre Monument

Paul Revere House

Situated in North Square, it is the oldest building in the city, dating back to 1676. Paul Revere made this his home from 1770-1800. It was restored by the Paul Revere Chapter of the Daughters of the American Revolution, and contains an interesting collection of relics. A small admission fee is charged.

It is interesting to know that Paul Revere, famous for his patriotic ride on April 18, 1775, was also a very able merchant, poet, and artist. He engraved the seal of the Commonwealth, and made a gun carriage for George Washington's use in the Continental Army.

Old North — Christ Church

It was in the belfry of this church that the lanterns were hung on April 18, 1775, which warned Paul Revere of the British advance. Opened for public worship in 1723, it was the second Episcopal church in the town, and contains the oldest chimes in North America. These are wonderfully sweet in tone.

Open free—on application to the sexton from 9 A. M. to 12 M. and from 1 P. M. to 4 P. M. week days. Sundays, after services.

Faneuil Hall — "Cradle of Liberty"

Where many important meetings, famous in the making of history, and dating from the Revolutionary movement, have been held.

Built in 1742 by Peter Faneuil and presented to Boston as a town hall. Burned in 1762, rebuilt in 1763 on original lines Enlarged in 1805 from plans by Charles Bulfinch, and remodeled in 1892. A market place occupies the first floor, a public hall the second, a balcony the third, and the upper floor is occupied by the "Ancient and Honorable Artillery Company," which is the oldest military organization in America. Here may be found a valuable historical collection, and many original paintings, illustrating early events in Colonial history. Hall open each week day 9 A. M. to 5 P. M.; Saturdays 9 A. M. to 12 M.

The Old State House

This historical old building located at the corner of Washington and State Streets contains many relics of Colonial and Revolutionary days, as well as a fine collection of photographs and old prints of Boston. These are under the charge of the Bostonian Society. It was built on the site of the first town house in 1713. In 1747 the interior was burned out, but as the outer walls were unimpaired they were used for the new building. It served as a city hall, town hall and here were held the General Court Sessions of the Commonwealth. Here, too, John Hancock was inaugurated first Governor of Massachusetts. The Declaration of Independence was read from the balcony on the State Street side. In front of this building occurred the Boston Massacre and the burning of stamp clearances. Building restored in 1882 and is open to visitors on week days from 9 A. M. to 4 P. M.; Saturdays, 9 A. M. to 1 P. M. Admission free.

King's Chapel — A Famous Landmark

Old South Meeting House

The first Episcopal Church, established in 1688, and is located at the corner of School and Tremont streets. Here, worshipped the Royal Governors and British officers during the siege of Boston. The rector, who was of the King's party, fled to Halifax, taking with him properties of the church, such as vestments and plate. These have since been restored. The present building was erected in 1754, and in 1784 became the first Unitarian Church in the U. S. Open daily from 9 A. M. to 12 M. Adjoining the chapel is the first burying ground in Boston, where are interred Winthrop and Shirley, Massachusetts' Bay Colony Governors. Also, Mary Chilton, who was the first woman to step on Plymouth Rock, from the Mayflower.

Now under the care of the Old South Association. Benjamin Franklin was baptized in the old building in 1706. The present building was erected in 1729. Many matters of great importance were decided here. The townsmen fought against the compulsory service of Massachusetts men in the English navy; demanded that the British withdraw their troops, and also decided what should be done with the tea which brought about the "Boston Tea Party." During the siege of Boston the British burned the pews and pulpit, and used the building for a riding school. It contains a very interesting collection of historical relics. A small admission fee is charged which is used for maintenance. Open week days from 9 A. M. to 4 P. M.

Park Street Church — Old Granary Burying Ground

Erected in 1810. Built on ground that was once occupied by the granary, where grain was dispensed to the poor. Also where the original sails of the "Constitution" were made. "America" was first sung here.

In the cemetery adjoining are buried John Hancock, Samuel Adams, Peter Faneuil, Paul Revere, the parents of Benjamin Franklin, the victims of the Boston Massacre, Robert Treat Paine, signer of the Declaration of Independence, and John Phillips, first mayor of Boston. Here too may be seen the grave of Mary Goose, author of "Mother Goose Rhymes" for children. Called "Old Granary" since 1737.

Bunker Hill Monument

On June 16th, 1775, Col. William Prescott, after prayers were said by President Langdell of Harvard College, left Cambridge, Mass., with Continental troops with instructions to fortify Bunker Hill, Charlestown, against the invasion of the British. Owing to the darkness when he arrived, he fortified Breed's Hill, and the battle was fought here on June 17, 1775. Hence it appears in the records as the Battle of Bunker Hill.

The monument is made of granite brought from Quincy, Mass., by the first railroad laid in this country. It is 30 feet square at the base and 220 feet in height.

The corner stone was laid in 1825, Lafayette and Daniel Webster taking part in the ceremony. Owing to lack of funds it lay unfinished for nearly twenty years, when public-spirited women raised the money for its completion. In 1843 Daniel Webster delivered his second oration at the dedication. A splendid view of the harbor and city may be obtained by climbing the spiral staircase of 295 steps. The building at the base contains many interesting relics of the battle.

United States Custom House Tower

An imposing tower, located at State and India Streets. It is Boston's only "Sky Scraper." Built on the old Custom House. The distance from sidewalk to apex is 498 feet. A clock whose dial measures 21½ feet in diameter occupies the space just below the 24th story. The contrast of old and new Boston is well shown in this picture. The corner of the building to the right is a part of Faneuil Hall.

The Boston Public Library, Copley Square

Trinity Church, From Old South

"The most important library in the world" was opened to the public in 1895. "Built by the People and Dedicated to the Advancement of Learning" is part of the inscription which may be read on the Copley Square side of the building. Here may be found many works of art by Abbey, Sargent, Bela Pratt, Macmonnies, and St. Gaudens. The mural paintings, illustrating the Quest of the Holy Grail, by Abbey, are in the delivery room. Bates Hall, the main reading room, was named in honor of a native of Massachusetts, Joshua Bates, who contributed very generously, when the Public Library was first established in 1852.

Special libraries and the Fine Arts Department occupy the upper floor, and on the walls may be seen the paintings by John Singer Sargent, "The Triumph of Religion." Free. Open week days 9 A. M. to 9 P. M., Sundays 12 M. to 9 P. M.

One of the most beautiful church buildings in the city, erected in 1872 and of Episcopal denomination.

The first Trinity, located on Summer street, was destroyed by fire.

Phillips Brooks, the noted pulpit orator, served as rector here for 22 years. He was later made Bishop of the Episcopal diocese. His statue by St. Gaudens stands on the Boylston street side of the church.

The mural decorations are by John La Farge.

Boston Museum of Fine Arts

Founded in 1870. It was then located in the Boston Athenaeum, but a new building was started in Copley Square in 1876 which was completed three years later. In 1890 it was found necessary to enlarge this building. The present site, consisting of twelve acres, was bought in 1899, at a cost of over one million dollars; this amount including later improvements. Many years of study, both here and abroad, were necessary to perfect the work inside so that the best lighting effects might be obtained and the galleries might be built to display art to the greatest advantage. The Japanese art collection is the finest, outside of Japan. The beautiful bronze statue, The Appeal to the Great Spirit, standing on the front lawn, is the work of Cyrus Dallin. Open free—10 to 5 week days; 1 to 5 Sundays. Closed on July 4, Thanksgiving and Christmas.

The Society of the South church, formed in 1668, moved from the famous Old South Meeting House, to its present home on Boylston street in 1874. Owing to the settling of the foundation the tower leans slightly from the perpendicular.

New Old South Church From Trinity

New England Conservatory of Music

Founded by Dr. Eben Tourjee, located at corner of Huntington Ave. and Gainsboro St., and is famous in this country as well as abroad. Madame Nordica, and other noted musicians received their training here.

HUNTINGTON AVENUE BUILDING

Boston Young Men's Christian Association

The Metropolitan Offices of the Association and the headquarters of the Huntington Avenue Branch and Northeastern University are located in this building. Other Branches are the Army and Navy Branch, City Square, Charlestown; the Boston and Maine Railroad Branch, 90 Friend Street; the Chinese Branch, 56-58 Tyler Street; and the Dorchester Center Community Branch, 720 Washington Street, Dorchester

Boston Cambridge Bridge

On the hillside in the background are seen the gilded dome of the Capitol building, and tower of the Custom House. It was near the site of this bridge that Longfellow was inspired to write the poem which begins "I Stood on the Bridge at Midnight."

Forsyth Dental Infirmary

Founded by Thos. A. Forsyth and his brother, John H. Forsyth. The first infirmary of its kind in the world. Here children under sixteen whose parents are unable to pay for private services in dentistry may be treated free of charge. Visitors are welcome.

Harvard Medical School

These impressive marble buildings are located on Longwood Avenue at the western entrance to the Back Bay Fens. They were completed in 1906, and opened at the time of a meeting of the American Medical Association in Boston. The Harvard school was the third medical school to be founded in the United States. In 1771 Dr. Ezekiel Hersey, a graduate of Harvard, gave the sum of $5,000 to Harvard College to be used "for a Professorship of Anatomy" on account of which bequest the school may be said to owe its origin. Visitors find the Museum of Comparative Anatomy especially interesting.

On Longwood Avenue in the centre of the section where many of the institutions which have made Boston famous for her educational advantages are located.

Massachusetts College of Pharmacy

Massachusetts Institute of Technology

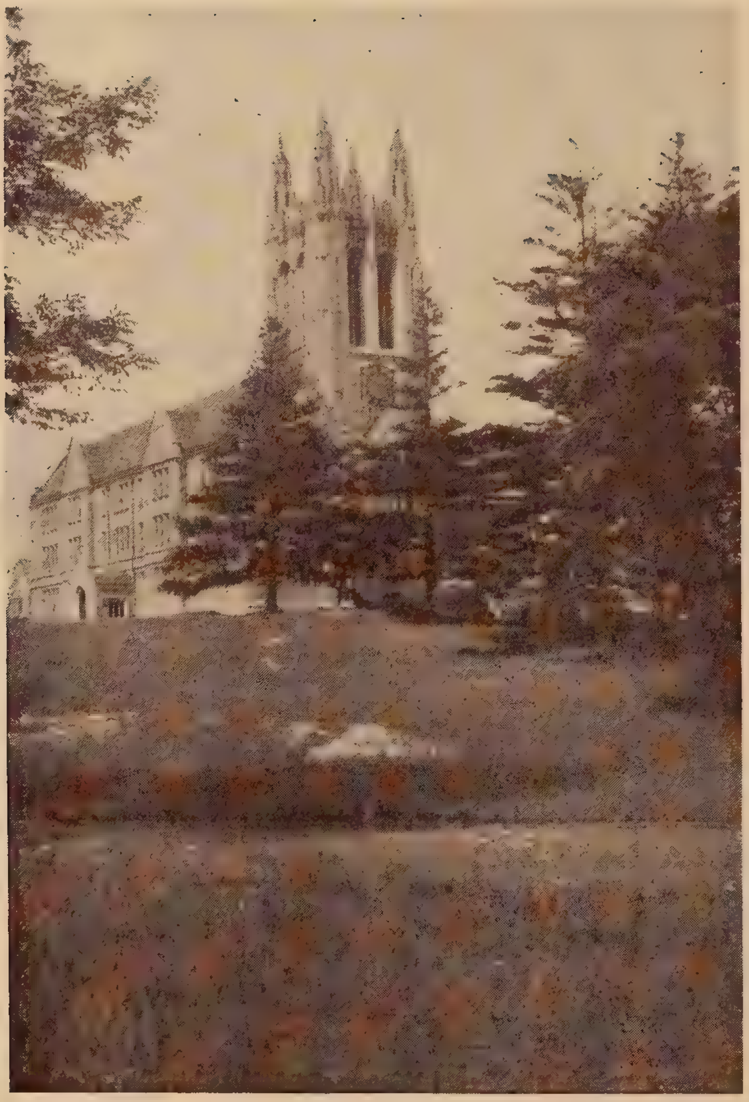
The buildings occupy an attractive site on the Cambridge side of the Charles River Basin. The administration building occupies the space under the dome. It is considered the leading technical school of the United States, its laboratories and work shops being equipped with every modern improvement. There are courses in Mechanical, Chemical, Electrical, Civil and Naval Engineering. Nearly ten million dollars have been expended on the buildings and equipment.

Located in the Fenway. It is the largest technical college for young women in the country, offering programmes in household economics, secretarial studies, library science, general science, social work, store service education, public health nursing, and landscape architecture. Founded in 1899, by provision in the will of John Simmons.

Simmons College

Tower Court, Wellesley College

Wellesley College was founded by H. F. Durant, and opened in 1875. An institution for the higher education of women, situated at Wellesley, Massachusetts, 15 miles west by south of Boston.



Boston College

Just beyond the Boston line in Newton are located the buildings of Boston College, which is conducted by the Jesuit Fathers. The buildings occupy an attractive site overlooking Chestnut Hill Reservoir.

Agassiz Hall, Radcliffe College

In 1894 the "Society for the Collegiate Instruction of Women" was incorporated Radcliffe College. The college is known as "Harvard Annex." Some of the courses are the same as those at Harvard, and given by the same instructors. Radcliffe diplomas have the seal of Harvard University.

Memorial Hall — Harvard University

Looking across the Harvard Yard may be seen the tower of Memorial Hall which was erected to the memory of Harvard men who served in the Civil War. The Ware collection of glass flowers in University Museum is of special interest to visiting tourists. Harvard was founded in 1637 and is the oldest college in the United States.

Longfellow House

Built in 1759. Colonial in structure and located at Brattle Street, Cambridge. George Washington made this his headquarters from 1775-1776. It is also known as the Craigie House. Henry Wadsworth Longfellow purchased it in 1843.

Eddy Memorial

Erected to the memory of Mary Baker Eddy, founder of The First Church of Christ, Scientist. Located in Mt. Auburn cemetery where Henry Wadsworth Longfellow, James Russell Lowell, Oliver Wendell Holmes, and Phillip Brooks are buried.

Lexington Green, Minuteman, Buckman Tavern

The story of the first skirmish of the American Revolution on Lexington Green is known in part to all who read their American history during schooldays. On April 19, 1775 the British entered Lexington, they were going to Concord to destroy the military stores of the Colonists. On Lexington Green the plucky Minutemen took their stand against more than eight times their number. The building to the right is the Buckman Tavern where the Minutemen gathered after the town had been warned by Paul Revere and William Dawes. On the Green are several tablets commemorating the events of the day, also the Old Revolutionary Monument in back of which is a vault containing the remains of the seven Minutemen who were killed by the British on Lexington Green.

Captain John Parker

This statue has stirred the patriotism of thousands of Americans. It was sculptured by Kitson and is one of the most satisfactory of Revolutionary monuments. It was John Parker who gave to his men this instruction: "Stand your ground. Don't fire unless fired upon; but if they mean to have a war, let it begin here."

Hancock Clark House

Located near Lexington Green and dates back to 1698. It served as a parsonage for Rev. John Hancock and later for the Rev. Jonas Clark. John Hancock and Samuel Adams were sleeping here, when Paul Revere rode by on the night of Apr. 18, 1775 to warn the countryside of the British advance. It contains many historic relics which are the property of the Lexington Historical Society. Open to visitors. Voluntary contribution.

Munroe Tavern

Built in 1695, located in Lexington. It was used as a hospital for British soldiers who were wounded at Lexington, also as headquarters for Earl Percy who had command of the British re-enforcements. Before leaving, the British killed the caretaker, and set the house on fire, but it was not destroyed. Open free to visitors from the middle of April to November.

Harrington House

One of the houses in existence at the time of the Battle of Lexington. It is located to the rear of the line of the Minutemen and was a close witness of the skirmish. Jonathan Harrington, who was wounded on the Green, dragged himself to the door and died at his wife's feet.

FANEUIL HALL

STATE HOUSE

MECHANICS BUILDING

OLD STATE HOUSE

LONGFELLOW'S HOME

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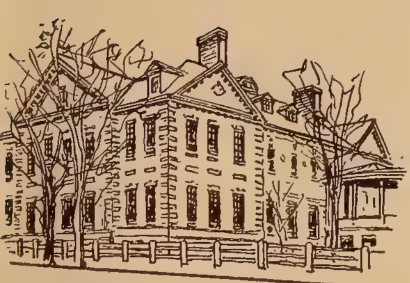
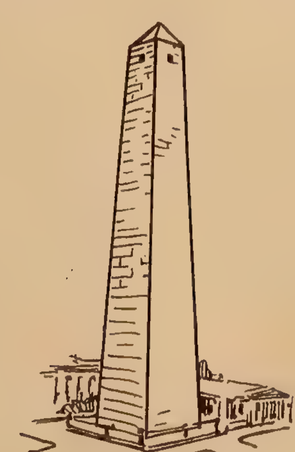


HARVARD UNION

SYMPHONY HALL

NORTH CHURCH

PAUL REVERE'S HOUSE



BUNKER HILL MONUMENT

KING'S CHAPEL

OLD SOUTH

Old North Bridge, Concord

"Here on the 19th of April, 1775, was made the first forcible resistance to British aggression. On the opposite bank were the American Militia. Here stood the Invading Army; and on this spot the first of the Enemy fell in the war of that Revolution which gave Independence to these United States." Thus the inscription reads on the Battle Monument. When the British fired upon the Americans at the North Bridge they killed Capt. Isaac Davis. Major Buttrick then gave the command, "Fire, fellow-soldiers for God's sake, fire!" Several volleys were interchanged. The British turned and fled. From the hill back of Elisha Jones' house the Americans watched the British gather in the center of the town. Colonel Smith decided to retreat and in spite of reinforcements under Earl Percy at Lexington the Americans pursued the Enemy to Charlestown. The British had no doubt that war had begun.

The Minute-Man, Concord

This famous statue was designed by Daniel Chester French, a resident of Concord. It was dedicated at the centennial celebration of 1875 at which President Grant was present. It represents the minute-man leaving the plow. Carved on the base is a verse from Emerson's "Concord Hymn":

By the rude bridge that arched the flood,
Their flag to April's breeze unfurled,
Here once the embattled farmers stood,
And fired the shot heard round the world.

Orchard House, Concord

When Louisa May Alcott was a young woman she came to this house with her father, Amos Bronson Alcott. The first part of "Little Women" was written here. The house is open to the public as a memorial to the Alcotts.

Emerson House

The house in which Ralph Waldo Emerson lived from 1835, the time of his second marriage, until his death in 1882. The library at the right of the entrance is very much as the philosopher left it.

The Old Manse, Concord

Described in Nathaniel Hawthorne's "Mosses from an Old Manse" this old house has many historic associations. Rev. William Emerson, grandparent of Ralph Waldo, watched, from an upper window, the battle at the Old North Bridge. In this house Ralph Waldo Emerson wrote his book, "Nature." Built in 1765.

Governor Hancock Mansion, formerly located on Beacon Street

JOHN HANCOCK

A TRIBUTE BY GOVERNOR WINTHROP OF MASSACHUSETTS

"Was there ever a more signal distinction vouchsafed to mortal man than that which was won and worn by John Hancock? Not altogether a great man, not without some grave defects of character; we remember nothing at this hour save his presidency of the Congress and his bold and noble signature to our Magna Charta.

"Behold him in the chair which is still standing in its old place, the very same chair in which Washington was to sit, the very same chair emblazoned on the back of which Franklin was to descry 'a rising, not a setting sun'; behold him, the young Boston merchant, not yet forty years of age, with a princely fortune at stake and with a price upon his head, sitting there in all the calm composure and dignity which so peculiarly characterized him, and which nothing seemed able to relax or ruffle.

"Behold him! He has risen for a moment. He has put the question. The Declaration is adopted. It is already late in the evening, but after a grace of three days the air will be vibrating with the joyous tones of the old bell in the cupola, proclaiming liberty to all mankind, with the corresponding acclamations of assembled multitudes."

House of Seven Gables, Salem

On Turner Street, Salem, is the Seven Gables Settlement, which is supported by sale of souvenirs and admissions to the house. This old house, with its hidden stairway and other interesting features, is a delightful place to visit. The house reminds one of the novel by Nathaniel Hawthorne, "The House of Seven Gables."

Salem Custom House

Where Nathaniel Hawthorne served as surveyor of the port of Salem for three years and where he received the inspiration to write "The Scarlet Letter." The Salem Custom House during the time of the sailing vessel was one of the most important in the country.

R. H. STEARNS CO.
Established
1847

MASONIC TEMPLE
Tremont Street and Temple Place
(About 1875)

At the Gateway to the Shopping District

Since Colonial Days the corner at Tremont Street and Temple Place has had notable history. Here the Colonial Sheriff lived, here stood the Usher Mansion, built by the first bookseller of the Colony. To this house the rector of King's Chapel brought his bride.

In 1830 there was erected here the Masonic Temple, later to become the Federal Court House. Since 1885 it has been the home of the retail business established in 1847 by R. H. Stearns. Standing at the Gateway of the Shopping District its location is ideal for its present purposes.

East India Marine Hall, Salem

During the early days of trading with the East Indies, Salem conducted a most extensive and profitable business. Some of the most important and interesting of the relics of these trading days are on exhibition in Marine Hall.

A museum containing the famous Peabody collection, also an extensive library of nearly one hundred thousand volumes.

Essex Institute, Salem

Sarcophagus and Peristyle

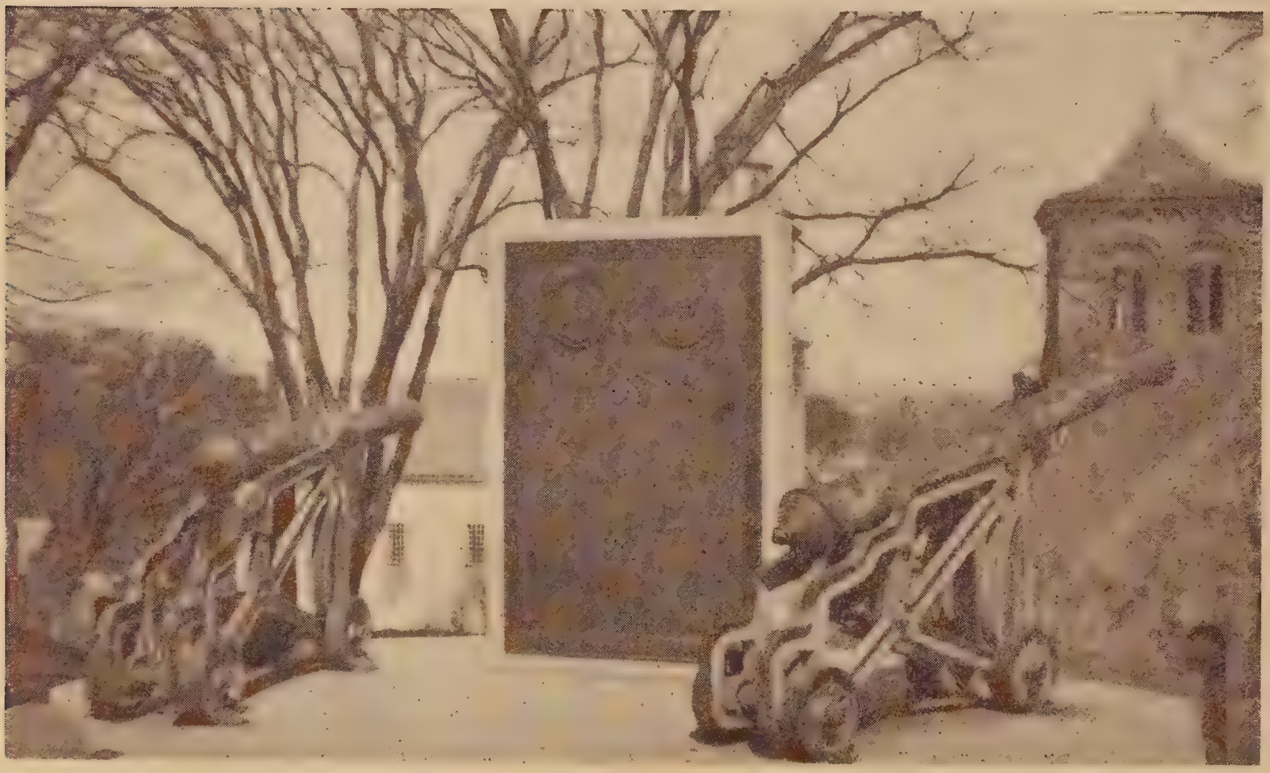
The three-hundredth anniversary of the landing of the Pilgrims was celebrated Dec. 21, 1920. To commemorate the event many changes were made on Cole's Hill, where the Pilgrims buried their dead in that first winter when half of the Mayflower passengers perished. Above is a recent photograph taken on Cole's Hill which shows the new Sarcophagus, Statue of Massasoit and top of Peristyle over Plymouth Rock. The Mayflower dropped anchor in Plymouth harbor Dec. 26, 1620 just a hundred days from the time she left Old Plymouth. There are many places of historic interest in Plymouth including, Plymouth Rock, Burial Hill, Site of The Old Fort, Site of Watch Tower, Graves of Governor Bradford and John Howland, National Monument to the Forefathers, Pilgrim Hall, Mayflower Relics, Harlow House and Howland House. Many tourists have found a trip to Plymouth from Boston most enjoyable.

Chief of the tribe of Indians who molested the Pilgrims; finally made peace and were invited to the First Thanksgiving.

Massasoit

Pilgrim Hall

Within its walls are many treasures of Pilgrim and Colonial days. Sargent's famous painting the "Landing" and Weir's "The Embarkation" adorn the walls. Many Mayflower relics, the Winslow relics, and personal belongings of the Pilgrims, delight the visitor to Pilgrim Hall.



Site of First Fort

Soon after the settlement in 1621 the Pilgrims built a fort on what is now known as Burial Hill. "Brass Cannon like these were named by Bradford and Winslow in the annals of Plymouth as mounted on the first Fort 1621 — These pieces were transmitted through the Honorable Artillery Company of London chartered 1537 and placed here by the Ancient and Honorable Artillery of Massachusetts chartered 1638 and dedicated October the 4th 1921." Thus the inscription reads.

THE PRESIDENT'S ROOM
STATE STREET TRUST COMPANY

Peristyle over Plymouth Rock

The rock on which the Pilgrims landed has been lowered to its original position so that to-day this historic relic is most inspiring. The Peristyle is part of the improvements which were made for the Tercentenary celebrations of the landing of the Pilgrims. The distant shore shown in the picture is beautiful Cape Cod.

National Monument to the Forefathers

This granite memorial to the Pilgrims was begun in 1859 and dedicated in 1889. Its total height is 81 feet; height of statue, 36 feet. On the smaller pedestal are seated figures emblematic of Law, Morality, Freedom and Education. From the base of the monument may be obtained a wonderful view of Plymouth, the harbor, the distant Duxbury shore and the Myles Standish Monument.

Standish House, Duxbury

The Standish house was built in 1666 by Alexander Standish, son of Myles. The grave of Myles Standish is in the old burial ground at South Duxbury. The monument erected to the memory of Myles Standish is on Captain's Hill, Duxbury.

John Alden House, Duxbury

The home of John and Priscilla Alden. "Archly the maiden smiled, and with eyes overrunning with laughter, said in a tremulous voice, 'Why don't you speak for yourself, John?' "—Longfellow's "Courtship of Myles Standish."

An advertising handbill, dated Nov. 24, 1810, for the Boston, Plymouth and Sandwich Mail Stage announced the leaving of the stage from Boston every Tuesday, Thursday and Saturday morning at 5 o'clock. To arrive in Sandwich the same evening. Passing through Quincy, Weymouth, Hingham, Scituate, Hanover, Pembrook, Duxbury, Kingston, Plymouth, to Sandwich. Fare from Boston to Scituate 1 doll. 25 cts. From Boston to Plymouth 2 dolls. 50 cts. From Boston to Sandwich 3 dolls. 63 cts.

The advertising maps and guides of The Royal Blue Line Company announce complete and dependable sightseeing service covering all the places of historic interest shown in "Notes and Pictures of Boston."

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This company has seen the gradual advancement of all types of automotive equipment for sightseeing. The demand for the manufacture of the latest De Luxe coaches has been created largely by the high standards aspired to and attained.

Royal Blue Line standards have convinced thousands of tourists that the most satisfactory way to see a city is in a sightseeing coach. Many who travel in their own car park the car in a garage and make reservations for seats.

Royal Blue Line service is established in many of the largest cities. The service is being extended and the latest information is included in the current folders to be obtained at leading hotels and tourist agencies.

A Royal Blue Line map and guide for Boston will be mailed free on request. Maps and guides for other cities where service is established may also be obtained. See latest list in current Boston folder and mention city for which you wish to obtain information. Please address Royal Blue Line Company, Hotel Brunswick, Boston, Mass.

Howland House, Plymouth

The last house in Plymouth whose walls heard the voices of the Pilgrims. The oldest known grave on historic Burial Hill is that of John Howland. His grave-stone has this inscription: "Hee was a Godly man and an ancient professor in the wayes of Christ. Hee was of the first comers into this land and was the last man that was left of those that came over in the shipp called the Mayflower that lived in Plymouth."

—*Plymouth Records.*

Fairbanks House, Dedham

Build by Jonathan Fayerbanks in 1636, who brought the timbers and tiles used in the building from England in 1633. It is reputed to be the oldest frame house in America and is owned by "The Fairbanks Family in America"; and is open to visitors from April 1 to Nov. 1. Dedham is situated 10 miles southwest of Boston.

Chapter Comets.

Comets conspicuous without a glass exhibit
365 three portions which graduate insensibly into each other. These are
a bright __nucleus__ surrounded by a fainter
mass called the __coma__, and the __tail__. The
nucleus and coma form the head of the
366 comet. The more brilliant the head is the
brighter and longer is the tail, and it is a
369 curious feature of the latter that it is invariably
turned from the sun. The actual length of
366 the shortest tail that is ever seen is almost always many
millions of miles. In rare cases, the tail is
split up into several branches.

Telescopic comets are much more
common than those plain to the unaided
eye. The former often exhibit no nucleus or
tail, many well-known comets among them
consisting of hardly anything but a patch of
foggy light. These are distinguishable from
nebulae by their ~~more or less~~ rapid motion
across the sky, while nebulae have a fixed
position. The spectroscope shows these comets

to consist entirely of gas, but gas as we know it does not altogether justify this conclusion.[a] Yet the fact that the smallest stars are seen through telescopic comets tens of thousands of miles in diameter proves their substance to be of an amazing tenuity.

Of comets which exhibit a nucleus and tail, there is hardly a doubt that they

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399 [a] The gaseous theory is met by several difficulties, according to Prof. Newcomb. First, a mass of gas would expand beyond all limits with no pressure to confine it, as in the celestial spaces. Again, experiment has shown that a gas cannot shine by its own light until it is heated to a temperature far above any that can possibly exist in situations where comets have been examined with the spectroscope. Finally, it is hardly possible that a purely gaseous comet would separate into innumerable widely detached pieces, as Biela's comet did.

7

are composed of some substance which is vaporized by the solar rays. We may then regard the tail as a stream of vapor rising from the boiling nucleus, conceiving the nucleus to be composed of water or some other volatile fluid.[a] But why the issuing stream of vapor always flies away from the sun is not yet understood. Comets thus acted upon must be subject to a constant waste when in the neighborhood of the sun, and this conclusion is strengthened by the fact that not a single comet of very short period has a considerable tail. This constant waste goes to prove that comets in general have been introduced into

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[a] Two reasons make it evident that the
.400 tail is not an appendage carried along by the comet: first, it is impossible for cohesion to exist in so thin a mass, which is, besides, constantly changing its form; and, 2dly, the rapidity with which the tail appears to move around the sun at perihelion, keeping the head always sunward, would tear it to pieces, and send the parts flying off in wide orbits of their own, if the movement was a real one.

"The year 1881 witnessed the first taking of the photograph of a comet, with a considerable portion of its tail. This picture shows that the tail, notwithstanding the brightness with which it appears to shine, is, at only a few degrees from the nucleus, 2 or 300 times less luminous than the moon."

M. Janssen, Pop. Sc. Mon. Feb. 1883

our system in modern times, for otherwise their
4.404 volatile matter must long ago have been evap-
orated. The near approach of two comets to the
sun,[a] those of 1680 and 1843, seems to prove
that the substance of these bodies is sometimes
metallic. For had these two comets been less
dense, Prof. Peirce has showed that they must
have been completely pulled apart by the enor-
mous tides generated at their perihelion passage.

The celestial spaces are so enormous that
405 there is hardly a chance of collision between the
earth and a comet, but even in the event of
a collision, this would be quite imperceptible to
us in the most of cases, so attenuate is the

Young [a] Four comets only, those of 1668, 1680, 1843, and
Pop. Sc. 1880, are known to have so small a perihelion
Aon. distance. The similarity of their orbits, excepting
an. 332 that of 1680, show them all to have come from
the same region of the heavens, this region being
near Sirius. This similarity may imply that a
single comet has visited the sun during the years
mentioned, or that a group or family of comets, very likely of
common origin, have separately followed each other.

[a] M. Arago says that the chances of an encounter between a comet and the Earth are almost the same as those of an encounter between two atomic grains of dust; one of which is whirled into the air at Paris, and the other in the United States.

It is one of the triumphs of modern astronomy that it has shown the occasional phenomena witnessed in our sky to be as harmless as the constantly-recurring phenomena, and thus rid the former of the terror which they were wont to inspire in the minds of the beholders.

– ½ fly leaf –

substance of comets in general.

Concerning the origin of comets, Prof. Newcomb says that we may regard them as stray fragments of original nebulous matter scattered throughout the great wilderness of space around us, and drawn towards our sun [b] one by one as the long ages elapse. The planets retard some so that they become permanent members of our system, while others have their speed increased by planetary neighborhood, and so leave our sun on a wider circuit and with less prospect of return than could be argued from their manner of approach.

37) The velocity of a comet indicates the form of its orbit: if the velocity corresponds to a certain limit the orbit is a parabola; if it exceeds this limit the orbit is an hyperbola; if it falls short of it the orbit is an ellipse or closed

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[b] The orbits of many if not all of the periodic comets pass near the orbits of some of the planets, which makes it probable that the former bodies were brought into our system by the attraction of the latter.

orbit, showing that the comet belongs to our
371 system.[a] The large majority of observed comets
have a velocity so near the parabolic limit
that it is possible that all of them belong to our
system. It is, however, certain that the return
of most of them will be delayed many centur-
ies or perhaps many thousand years. The ve-
373 locity of comets, diminishing with increase of
distance from the sun, like that of the plan-
Guillemin ets, varies between very large limits: thus the
p. 253 comet of 1680 scarcely traverses at its aphelion
more than 3 yards a second, while its velocity
Mitchell [illegible] at perihelion is nearly 300 miles a second.
N. 371 Quite a number of comets have been observed at

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[a] "There is this very important difference between an elliptical and a parabolic orbit—that the former is closed up, and a comet moving in it must come back sometime, whereas the two branches of the latter extend out into infinite space without ever meeting. A comet moving in a parabolic orbit will, therefore, never return, but, after once sweeping past the sun will continue to recede into infinite space forever. The same thing will happen if the comet moves in an hyperbola, which is the 3d class of orbit that may be described under the influence of gravitation. In a parabola, the slightest retardation of a comet would change the orbit into an ellipse, the velocity being barely sufficient to carry the comet off forever, whereas in an hyperbola, there is more or less velocity to spare. Thus the parabola is a sort of dividing curve between the hyperbola and the ellipse."

(Pop. Astron. by Simon Newcomb.)

several returns and thus their exact periods determined. These range generally from about 3
Y.527 to 7 years, there being two (Tuttle's and Halley's) whose respective periods are 13 and 76 years.

Chambers
A returning comet is not known by its aspect, which undergoes changes, but it is presumed that, whenever one follows the path of a former one, the two bodies are identical. For it is in accordance with the laws of motion that a comet, like a planet, should pursue the same track at all times.

The planes of the cometary orbits have
S.p.242 every possible inclination to that of the ecliptic, and hence comets are not confined to the zodiac, but appear in every quarter of the heavens. They also move along the sky in every possible direction.

N.374 About 700 comets have been observed since the Christian era, 200 of which are telescopic. Of the latter sort several new ones are discovered every year, sometimes as many as 6 or 8. The entire number is doubtless but a very small
373 fraction of all that exist, for, owing to its elongated orbit a comet can only be seen when near its

~~Most of the comets revolve around the sun in extremely elongated ellipses.~~

perihelion, and then seldom unless the perihelion lie inside the orbit of the earth, or but little outside of it. Comets usually remain visible only a few days or weeks.

Remarkable Comets. The great comet
374 of 1680 is remarkable both for its brilliancy, and for Newton's proving by it that comets move under the influence of the gravitation of the sun. Halley suspected this comet to be identical
375 with three great ones seen previously at intervals of 575 years. The tail of this comet, at its greatest length, exceeded the interval between the sun and earth by 30 million miles.

Herschel's Outs. of Astron. 302

N. 375 Halley's comet, observed by Halley in 1682, is celebrated for being the first whose period was determined and its reappearance predicted.

Rolfe & Gillet [illegible]

N. 376 As the time for this approached, in 1759, it became extremely interesting to know how far the attraction of the planets might interfere with the comet's progress. Da. p. 91. This computation was undertaken and accomplished by Clairaut, who had to calculate the effects of the planets on the comet's motion during its entire period of 76 years, a work of

immense itinerary. The comet appeared according to calculation, within a few days. This comet may
Natur be traced in history as far back as the year 1 B.C.
Its perihelion is nearer the sun than Venus and
Bromwich its aphelion beyond the orbit of Neptune.

<u>Biela's</u> comet, which was discovered in
N.378 1826, was found to have a period of 6 3/4 years. Two months after its appearance in 1845 it was found to have suffered an accident, of which no explanation has ever been given. The comet had

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2 <u>Lexell's</u> comet is a striking example of
Gen. Int. of Astron. 313 this interference. This comet was found by Lexell, in 1770, to have a period of about 5 1/2 years, but, though a very bright comet it has not been seen since. The same comet passed very near Jupiter both in 1767 and 1779, which no doubt greatly altered its course, reducing its orbit on the former occasion, and again enlarging it on the latter. In returning to perihelion in 1770 it was hidden in the sun's rays. It is worthy of notice that the satellites of Jupiter showed no change of movement arising from the comet's proximity, proving the inferiority of its mass.

separated into two distinct comets, and thus appeared at its next and last return in 1852.

N. 379 In 1872, when it would have been due in our sky had it continued its regular periods, some invisible fragments were passing along its orbit, and produced a small meteoric shower. From
378 this the total dissolution of the comet is inferred, such an event having happened in no other case, so far as known.

379 The great comet of 1843 was visible in full daylight. It passed nearer to the sun than any other known body, so near it, in fact, as almost to graze it. In this vicinity it was
Her. Out. of Astron. 319 subjected to a heat 24½ times greater than suffices to melt agate and rock crystal, but its immense perihelion velocity of 366 miles a second exposed it to this extremity but for a short time.

N. 379 <u>Donati's</u> comet of 1858 was one of the most magnificent of modern times. It was seen ap-
380 proaching the sun as a telescopic object for nearly 3 months, but grew rapidly after becoming visible to the naked eye. At the time of its greatest brilliancy its tail was 40° in length, with a breadth

of 10° at its outer end. This comet is estimated to have
Newcomb & Holden a period of 1950 years.

N. 381 Encke's comet has most excited the
attention of astronomers in recent times, from
its being the first known case of a comet of short
period, its orbit being described in about 1200
382 days. This comet is also distinguished by reason
of Encke's supposition that it meets with a resisting medium in space, and is therefore
being gradually drawn towards the sun, as
Encke discovered to be the fact by a constant
Per. shortening of its period.[a] This comet has no
309 tail and only a small, ill-defined nucleus.

x The great comet of 1811 was visible 10 months.
Mitchell Its aphelion distance is about 14 times that of

N. 382 [a] Later examinations of the motions of this comet have partly confirmed Encke's results and partly disproved them, the comet having made two successive revolutions between 1865 and 1871 without any change of period.

384 As no other comets are known to be affected by a resisting medium, there is probably none in this case. (Newcomb.)

Neptune, and its period about 3000 years, as estimated.
A curious relation has been discovered between comets and meteors. This will be considered in treating of the next subject.

N° 384

Meteors and Shooting-Stars.

Those who are accustomed to observe the sky often see what looks like a star shooting through a short space, and then suddenly disappearing. Three or four such stars may generally be seen in the course of an hour. Sometimes they are so
384 brilliant as to illuminate the whole heavens, and they are then known as meteors,[a] a term which astronomers also apply to the shooting-stars.
385 Meteors have on some occasions shown

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[a] "The remarkable meteor of Aug. 18, 1783, traversed the whole of Europe, from Shetland to Rome, with a velocity of about 30 miles per second, at a height of 50 miles from the surface of the earth, with a light greatly surpassing that of the full moon, and a real diameter of fully half a mile. Yet with these vast dimensions, it changed its form visibly, and at length quietly separated into several distinct bodies accompanying each other in parallel courses and each followed by a 'tail or train.'" Herschel's Outlines of Astronomy

Descript. Astron. by G. F. Chambers
also Kirkwood Met. &c. [illegible]
June 1882

themselves in such numbers as to convince the terrified beholders that the end of the world had come. An ancient writer says of the great meteoric shower of 1202: 'The stars flew about the entire night, scattering on the right hand and on the left like a swarm of locusts; people were thrown into consternation and cried out to God with confused clamor." [a] In 1799, on Nov. 12, a remarkable shower

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[a] "Condé, in his history of the dominion of the Arabs, speaking of the year 902 A. D., states that in the month of Oct., on the night of the death of Ibrahim - Ben - Ahmed, an immense number of falling stars were seen to spread themselves over the face of the sky like rain, and that the year in question was thenceforth called the 'year of Stars.' It is also recorded that a remarkable display took place in England and France on Apr. 4, 1095. The stars seemed 'falling like a shower of rain from heaven upon the Earth.' In the Chronicle of Rheims we read that the stars in heaven were driven like dust before the wind."

Descriptive Astron. by Geo. F. Chambers.

The effect of the great star-shower of 1833 upon the colored people of the South, as has been frequently

was seen by Humboldt and Bonpland, who were then on the Andes. The next great shower was seen in this country in Nov. 1833. Dating back to the former one, the astronomer Olbers at once conceived the
1. 385 idea of a 34-year period and predicted a return of the display in 1867, which came accordingly on
383 the 13th of Nov. These showers take place in silence
386 far above the region of the clouds, but rarely, meteors of extreme brilliancy are followed by a loud report, and still more rarely, metallic or stony masses, called aerolites, fall to the earth. These, on examination, are found to contain no new chemical elements, yet the combination of their elements is quite unlike anything we know of on the earth, showing they must have originated outside of it.

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described, was appalling in the extreme. Prof. Olmsted, witnessing this shower in Boston, estimated the number seen during the entire display of 7 hours to exceed 240,000. He compared the number seen at the moment of maximum to half the number of flakes which are seen in the air during an ordinary fall of snow.

N 387 Concerning the cause of meteors, it is now universally conceded that the celestial spaces contain multitudes of minute bodies moving around the sun in every form of orbit.[a] The nature of the minutest sort is unknown, but these strike our atmosphere as the earth encounters them[b] in its

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387 [a] "These may not average more than one in a million of cubic miles, and yet their total number exceeds all calculation." (Newcomb.)

387 [b] The earth moves in its orbit at the rate of 98,000 feet per second, or 1100 miles a minute. If it come to an aerolite or mass of metallic rock, or even a cloudlet of gas at rest in space, its contact with our air evolves nearly 600,000° of heat. $(98,000 \div (125))^2$ This result is heightened by the velocity of the meteors themselves, which, if observations can be relied upon,
259 varies from 20 to 40 miles per second." Sir Wm. Thompson
387 son found that a thermometer placed in front of a rapidly moving body rose 1° when the body moved through the air at the rate of 125 feet per second. With higher velocities the increase of temperature was proportional to the square of the velocity, being 4° with a velocity of 250 feet; 16° with one of 500 feet per

annual motion, and are in consequence burned,
the light of which burning forms the shooting-star.
388 If a body is so large and firm as to pass through
the atmosphere and reach the earth without
being consumed, we have an aerolite. This is fre-
389 quently broken to pieces by the enormous resistance
of the lower atmosphere, and with such violence
that it seems to explode, for there is good reason
to believe that the noise is due to the collision.
But in the case of meteoric showers, we have a
390 swarm of minute meteors all moving in one di-
rection in parallel lines, the vanishing point of
Rolfe 130 which, in the heavens, is called the radiant point.
N. 391 This point is really that towards which the earth
is moving at the time, and hence the approaching

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second, and so on. This result is in exact accordance with the mechanical theory of heat. It is now established that heat is only a certain form of motion; that hot air differs from cold air only in a more rapid vibration of its molecules and that it communicates its heat to other bodies simply by striking them with its molecules, and thus setting their molecules in vibration." (Newcomb.)

meteors seem to radiate from it, just as falling flakes
¶ 391 of snow in a calm seem to separate from the line
of flakes directly over an observer who is looking
upwards at them. Every year, about the 13th of Nov.
395 and 9th of Aug. shooting stars are much more nu-
merous than on ordinary nights, while the Nov.
shower, as already mentioned, is very remarkable at
393 intervals of about 33 years. Of these two annual
displays, astronomers have concluded that the
swarm which cause the Nov. shower revolve
around the sun in a definite orbit, which inter-
392 ¶ sects the orbit of the earth at the point which the
latter now passes on Nov. 13. The orbit of these me-
393 (2d p) teors being determined from their radiant point,
Lockyer which lies in the constellation Leo, it was found
¶ 393 (3d p) that Tempel's comet was moving in the very same
orbit, and hence the meteors are concluded to be a
395, 6¶ swarm of detached particles following in the wake
of the comet. In the process of time this swarm
397 will become equally scattered around their orbit;
396 from the swiftest members of it overtaking the
slowest, but at present the thickest portion of it
392, (top) extends along about 1/15 of the orbit. The earth en-
counters this portion on the average once in 33.25

years, and hence the remarkable showers which occur at intervals of this length. The velocity of
P. 388 the Nov. meteors is 26 miles a second.

The orbit of the Aug. meteors, which radiate
Perseids from a point in the constellation Perseus, has also been found to be substantially the same with that
P. 395 of a comet observed in 1862, and these meteors are therefore concluded to follow the comet, as in
397 the Nov. case.[a] As nearly the same sort of shower occurs every Aug. the meteors seem to be completely scattered around their orbit, from which it is inferred
398 that the Aug. group has been in our system a much longer time than the Nov. group. The meteoric shower
396 mentioned in connection with Biela's lost comet

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[a] "This is no doubt true of all comets, the meteoroids being fragments or débris of the comet. Hence Prof. Newton" (to whose researches a knowledge of the cause of these periodical showers is largely due) "regards a comet as formed by the massing together of meteoroids. The nucleus of the brighter comets may either be a more condensed mass of such bodies or it may be a solid or liquid body itself."

Newcomb and Holden's Astronomy.

is another striking case of the connection between comets and meteors.

Careful investigations of the Nov. showers give
N. 387 the general result that the meteors are first seen at an average height of 75 miles, and disappear at a height of 55 miles. It is not known positively that any meteor commences at a height much greater than 100 miles which is very nearly the altitude at which the most brilliant meteors are ever seen. These phenomena seem to indicate that our atmosphere really extends to a height of between 100 and 110 miles.

395 The Aug. meteors are remarkable in that they leave trails[a] of luminous vapor which often last several seconds.

It is calculated that the average number of meteors which traverse our atmosphere daily, and which are large enough to be visible to the naked eye in a dark clear night is no less than 7½ millions, and that the telescopic meteors will increase this number to 400 millions. The daily fall of this material is supposed to amount to 500 tons. The particles striking the earth with an average velocity of 15 miles a second

The Zodiacal Light.

This object when seen in our latitude is a faint cone of light proceeding from the direction of the sun, either before sunrise or after sunset. The length of the cone from its vertex to the sun, varies from 40° to 90° and sometimes more and the breadth of its base perpendicular to its length from 8° to 30°. The axis of the cone lies very nearly in the plane of the ecliptic, and the light can therefore be best seen with us when the course of the ecliptic, at morning and evening twilight, is most nearly perpendicular to the horizon, which happens soon after sunset in spring and before sunrise in the autumn.[a]

[a] This situation of the ecliptic is shown in the former case, by setting the western quarter of an artificial horizon, adjusted to our latitude, over the vernal equinoctial point on a globe; and in the latter case by setting the eastern quarter of the horizon over the autumnal equinoctial point. When the course of the ecliptic, at twilight, is near the horizon, the light is extinguished by the great thickness of atmosphere through which it has to pass.

At the equator, where the ecliptic always rises high above the horizon, the light can be seen about equally well all the year round,[a] and in a very clear atmosphere it has been traced entirely across the heavens from east to west thus forming a complete ring.[b]

It is manifest that this light is a lens-shaped appendage of some sort surrounding the sun, and reaching out a little beyond the earth's orbit. According to Prof. Wright, who has made a very careful study of the subject, its spectrum is probably that of

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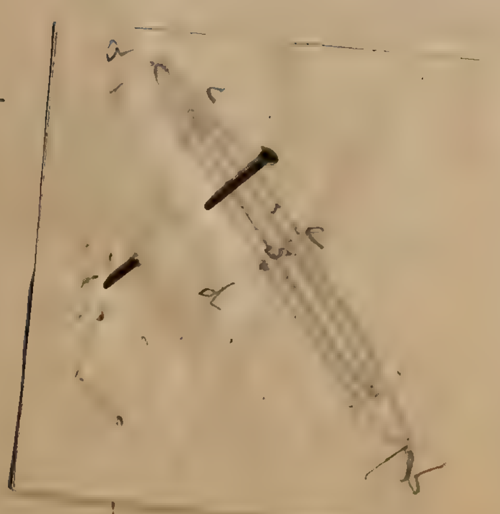
[a] Humboldt describes it as a perpetual aurora, in this region.

[b] This shows it to reach beyond the orbit of the earth (See "Mercury" p.) along some of its radii, if not all. Seen at 90°, it would be tangent to the earth's orbit, and at a less distance within the orbit.

[c] The figure represents a hoop of considerable breadth and thickness, revolving round a small sphere s, which is visible if we suppose the hoop to be transparent. Now if we conceive the bodies constituting the zodiacal-



reflected sunlight, which is in favor of the theory that it arises from a cloud of meteoroids revolving around the sun. – p.

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light to be grouped into a similar figure, similarly situated to the eye, it will be evident that the light extends neither above nor below the plane of the ecliptic for a distance equal to sc, although in appearance it surrounds the sun at s on all sides. Also, the ends a and b being more remote from the eye than the line sd by a distance equal to the radius of the figure the light would fade gradually towards the ends. Lastly, if we suppose the figure to be compressed into a convex outline, the light will assume different lengths between a and b, and different widths between d and e, as it revolves. The same change of aspect must follow from the earth's revolution around the sun. If the bodies in question reach inward to the sun's surface forming a disk instead of a ring the general appearance of the light would be the same, except that its intensity would be heightened.

a "The annals of the Chinese contain the earliest records of celestial phenomena; but the Chaldean ~~observers~~ observations are more interesting to Europeans on account of their connexion with modern astronomy." His. of Phy. Astron. by Robert Grant.

b Further it has only been possible by the aid of the spectroscope, a very recent instrument, to learn anything of the constitution of the heavenly bodies

Chapter I. Introductory.

Astronomy is known to have occupied the attention of mankind in very ancient times from the fact that the earliest records of the science which have come down to us imply quite an extended career of previous observation and discovery. This primitive knowledge compared with the state of the science to-day, was, however, of the simplest kind and very few important additions were made to it for many centuries. These facts are not surprising when we consider how much has been learned by means of the telescope, which instrument, as we know, was not invented until the time of Galileo. Not long after this great accession to astronomy, the invention of the Differential and Integral Calculus furnished another powerful aid by its marvellous adaptation to the resolution of problems of the higher order, and no small assistance in the same line has also been contibuted by the so-called system of logarithms. Further &c (See margin)

But apart from these modern contrivances the progress of astronomy was rendered difficult and slow by the very nature of the pursuit. The planetary movements are ~~highly~~ exceedingly complicated to an observer on the earth, ~~[illegible]~~ ~~[illegible] that was given them,~~ ~~[illegible]~~ while the stellar movements are so imperceptible as only to be known by a comparison of charts exhibiting the heavens at widely distant intervals of time or, in a few cases, by the aid of a powerful magnifying glass.

The earliest catalogue of stars which we possess

Further it has only been possible by means of the spectroscope or very recent invention to learn anything of the constitution of the heavenly bodies.

was constructed by Hipparchus, whose discoveries, but more especially his methodical treatment of the subject, have very justly entitled him to be called the "Father of Astronomy." Among his lesser improvements, Hipparchus made an exact division of the ecliptic and zodiac into signs of 30° each, which he named from the constellations most nearly corresponding to them, the constellations being found wholly insufficient for purposes of reckoning.[a]

It has been fancied that the names Aries, Taurus, etc. were suggested by the seasons; for instance, that the spring signs mark the bringing forth of young by the flocks and herds; that Leo symbolizes the fierce heat of summer, Scorpio the presence of venomous reptiles in October, and so on. But all this, or any other theory accounting for these names, is mere conjecture. They were conferred hundreds, or perhaps thousands of years before the

Newcomb p.

[a] Owing to precession (see p.) the signs have fallen about 30° behind the constellations, the first point of the sign Aries being now in the western part of the constellation Pisces.

Christian era, and we have no way of determining the ideas of their authors.

Professional astronomers no longer make any use of the signs of the ecliptic, but divide this circle into 360°, like any other circle, the count commencing at the vernal equinox, and following the direction of the sun's motion all the way round to 360°.

It was very natural for the early astronomers to consider the earth at rest and in the centre of the universe, while the heavenly bodies moved in circles around it. This theory of the "system of the world" is fully set forth in the "Almagest" of Ptolemy, a work composed in the second century of our era, and from which nearly all our knowledge of ancient astronomy as a science is derived. The planets described a very absurd figure around their centre, according to Ptolemy, yet the weight of his authority not only overruled the arguments of others who affirmed, even in his day, that the earth was in motion, but maintained his views through a period of 14 centuries. a (page 4)

There is some reason for believing that Pythagoras taught that the sun, and not the earth, was the centre of the planetary motions but Copernicus has the honor of proving this fact to the world, as well as the diurnal revolution of the earth by the powerful reasons which he brought forward for their support, in particular in his great work.

The Copernican system enables us to determine the relative distances of the planets from the sun, or the proportions of the solar system. For the annual motion of the earth causes the outer planets to describe an apparent circle of the same magnitude as the orbit of the earth, which circle appears larger or smaller according to the distance at which the observer

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[a] The pertinacity with which the disciples of the ancient astronomical creed received its dogmas after they had been refuted by the revelations of the telescope is hardly to be credited in these days of research and discovery, but the fact is an evidence of the blind deference which men often pay to an established custom or belief.

is situated. This circle is described around the mean position[a] of the planet, so that it is seen to swing alternately on each side of this position every six months: this libration being about 2°, but not more than 1° on either side of its mean position. The relative distances of the inner planets from the sun are known by their greatest elongation.

Tycho Brahe, who was born 3 years after the death of Copernicus, is chiefly famed for his observations of the positions of the heavenly bodies, which observations enabled Kepler to discover his celebrated laws of planetary motion. Tycho rejected the earth's annual motion, because the stars,

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a. This position shows the actual mean motion of the planet freed from the effects of the earth's motion. In the case of the inner planets the sidereal period. See the "Summary" for the values. tabulations of time, these show their actual motions while the difference between this and their synodical periods shows the apparent motion given to them by the annual motion of the earth.

which are outside the Solar System, like Mars, Jupiter and Saturn, did not describe an apparent circle annually, like those planets, as the result of such a motion. The stars must consequently be at an inaccessible distance if the earth really revolved around the sun. At the same time Tycho could not doubt, from the proofs given by Copernicus, that the planets revolved around the sun. He therefore adopted ~~to explain the absence~~ a theory consistent with his opinions, which ~~of parallax in the stars Tycho then said that he~~ was that the sun ~~was itself carried~~ described an annual orbit around the earth, while the latter was at rest at the centre of the universe.

Kepler assisted Tycho Brahe for a while in his astronomical labors, but did not adopt the singular system of his master, being assured that the Copernican system was the true one. The accuracy of Tycho's observations showed Kepler, however, that the planetary motions could not be performed in uniform circles, as Copernicus believed, in accordance with the ancient theory. Kepler therefore set himself to determine the true laws of these motions, beginning with an

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Put in note here Kepler discovered these 3 laws,

investigations of the motions of Mars, the most favorable planet for his purpose. After an incredible amount of labor, occupying many years, he discovered the three laws already referred to which are as follows:

1. *Every planet describes an ellipse*[a], in one of whose foci the sun is situated.

~~Ellip~~.

2. The radius vector of the planet, ~~radius vector~~ or the imaginary line joining its centre to the *sun's*, passes over *equal areas* of *the ellipse* in equal times.

3. *The squares of the periodic times of any two*

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[a] An ellipse is drawn in this way: fasten the ends of a string at two points upon a plain surface, with the string considerably longer than the distance between the points. Then keeping the string stretched by a pencil held perpendicularly within its arc move the pencil entirely around the string. The greater the distance between the two points, called *foci*, the length of the string remaining the same, as in the case of the planets, the greater the difference between their distances, severally, from the sun at perihelion and aphelion (See p.) the more elliptic is the figure described in either case.

The solution of these problems lead us to the consideration of one of the sublimest discoveries that has ever been made by the human intellect, the discovery of universal Gravitation by the consummate philosopher and mathematician Sir Isaac Newton —

(See a. page 9)

planets are ~~to each other~~ in the same proportion as the cubes of their mean distances from the sun.

These laws seemed to represent perfectly, in Kepler's day, the motions of the planets, but with more refined observations came the knowledge that the planets deviate slightly from them in the course of many successive revolutions. The result is that there is a material change in the form and position of the planetary orbits after the lapse of ages. Here, then, was another problem to be solved: What is the cause of this departure from Kepler's laws, and first why do the laws exist at all? Why should a planet describe an ellipse? Why should its radius vector describe equal areas of the ellipse in equal times? Why should there be an exact relation between the distances and the periods of the planets? The solution of these prob- ~~It was impossible to answer~~ lems [illegible] to the completion [illegible] of some of the ~~any of these questions until the general laws of~~ [illegible] that has ever been ~~motion were fully un~~derstood, an important step made by the [illegible] intellect [illegible] in the discovery of which was taken by Galileo the [illegible] thought [illegible] Germany ~~great contemporary of Kepler. Galileo was followed~~ philosopher & mathematician, Sir Isaac ~~by Huyghens's discovery of~~ Newton. (See a p. 9) ~~the laws of centrifugal force~~, and thus [illegible] the way

~~clearly prepared for Newton's great discovery of the universal Gravitation which explains every phenom~~enon ~~of the celestial motions.~~

Chapter II. Universal Gravitation.

It was understood long before Newton's time that bodies fall to the ground because the earth attracts them. Indeed, this conclusion seems unavoidable when once the earth is known to be a sphere. Newton did not show, therefore, or wish to know why an apple falls from a tree,

~~a Gravity explains every phenomenon of the celestial motions~~
with ~~With~~ two exceptions. There are still slow changes in the motion of the moon which gravitation has not yet accounted for. These are possibly only apparent, and really due to a minute retardation of the diurnal motion of the earth, by which the day is imperceptibly lengthened.

2dly, the motion of the perihelion of Mercury is about 40" a century greater than follows from the gravitation of the other planets. This again is possibly due to the action of the cloud-like mass constituting the zodiacal light.

but he answered a much harder question by proving mathematically that the force which causes it to fall is identical with that which causes a planet or a moon to describe an orbit around its centre.[a]

If a cannon ball be projected horizontally it will describe a curve and finally fall to the ground. If it were possible to project a cannon ball with a force that would make the curvature of its path less than the curvature of the earth's surface, the ball in this case would manifestly never reach the earth, but would continue to circulate around it: in other words, the ball would be a satellite of the earth. Granting the ball could be fired from a terrestrial summit reaching even to the moon's orbit, if this were possible, the result would be the same, provided the velocity of the ball was always such that it fell from the straight line in which it was fired no faster than the earth itself curves away. Newton's question then was simply this: Does not the attraction of the earth keep the moon in her orbit by causing her to fall continually.

[a] Newton's attempt to extend the law of gravitation, as known on the earth, to the entire solar system has been compared, in originality and boldness of conception, to the attempt of Columbus to discover an imagined continent across an ocean that was believed to be impassable.

out of the direction of the straight line which she would otherwise pursue: Had Newton known the true diameter of the earth at that time, he would very soon have obtained an affirmative answer to his question. For it was well known that the moon's distance was 60 semi-diameters of the earth, which distance reckoned in miles easily gave the circumference of the moon's orbit, and hence the amount of the moon's motion in one second of time, from which her fall towards the earth in the same interval could be computed. The amount of this fall then multiplied by the square of 60 ought to give 16 feet, the fall in a second at the earth's surface. But it gave only about 14, and Newton dropped the subject. 20 years later, hearing that Picard's measures showed the earth to be $\frac{1}{5}$ larger than he had supposed, he again attacked the problem and this time with the expected result.

But preliminary to establishing an identity between the force which causes a body to fall to the earth and a satellite to revolve around it Newton applied himself

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himself to determine the magnitude of the force which retains a body in a circular orbit, the force being continu[ally] directed to the centre of the ~~circle~~ circle. This he did by means of the relation between the periodic times and the distances of the planets as stated in Kepler's 3^d law, thus finding the force to vary according to the inverse square of the distance. Hence as we have seen, the moon's fall in a second of time had to be multiplied by the square of 60 in order to compare it with the fall of a body at the surface of the earth in the same interval. But, as in reality the planets move in elliptic orbits with the Sun in the focus, whereby the distance between the attracting and the attracted body is subject to continual variation, it becomes necessary to ascertain the corresponding variation of the ~~force~~ force. This rendered the question much more complicated requiring in fact the highest powers of invention when we consider the state of mechanical science in Newton's time. Newton's inventive genius however devised the means of its solution and he found that the centripetal force varied inversely as the square of the distance from the focus of the ellipse. Further Newton demonstrated that a body projected in free space and exposed to the action of a central force, varying according to the inverse square of the distances would revolve in a curvilinear orbit which would be some one of the conic sections. It might be a circle

, an ellipse, a parabola, or any hyperbola, but it must necessarily be one of them — the question as to the particular species of curve depending entirely on the primitive position of the body and the velocity of the impulse

a very simple process - (see p. 12)

R. G. 2 7

R. G. 2 24

of the sun. Assuming the amount of the attraction to vary everywhere according to the inverse square of the distance from the attracting body, Newton demonstrated the relation existing between the periods and distances to be the same as Kepler had already determined by another method. Thus the celestial motions

A very similar process shows the bearing of gravity upon Kepler's 3rd law. According to this law the cubes of the mean distances of the planets divided by the squares of their periods give the same quotient for each planet. But if we proceed in the same way with the satellites of Jupiter, the quotient will be the same for each satellite, but 1/1047 as great as for the planets, showing the sun to be 1047 times as heavy as Jupiter. We thus have a ready way of comparing the weights of those planets which have satellites with the weight of the sun.

We have seen that Kepler's laws do not represent exactly the motions of the planets. This is because the sun does not alone attract them but they

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attract each other and even act upon the sun itself, causing its centre to be perpetually displaced in space according as they combine their masses on one side or another.[a] This is not all. The smallest particle of a body, a speck of dust floating in our atmosphere, for instance, is known to possess the power of attraction because it has weight. Hence we conclude that all the particles composing the earth combine to keep objects upon its surface, and not that the whole [illegible]

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[a] The path of the sun's centre resulting from the action of the planets, is a complicated curve. It is found by computation that the distance between the solar centre and the centre of gravity of the system can never be equal to the solar diameter.

The action of the planets on each other has given rise to the profoundest questions in mathematical astronomy. The discussion of these questions has rendered illustrious the names of Clairaut, D'Alembert, Euler, Lagrange and Laplace and given us the two great works which form the basis of nearly everything that has since been achieved on the subject. We refer to the "Mécanique Céleste" of Laplace, and the "Mécanique Analytique" of Lagrange.

force of contact of the earth
~~accomplishes this by a single push.~~

Chapter III.

The Solar System. — Apparent Motions of the Heavenly Bodies. — Eclipses of the Sun and Moon. — Time. — Precession of the Equinoxes. — The Tides.

The ancients long ago perceived that 5 of the stars, with the sun and moon, were in constant motion among the great mass of the celestial bodies. They therefore called these 7 objects the wandering stars or planets, from which it followed that the others, in which no such motion was apparent, were designated the fixed stars. We now know that there are two great primary planets outside the 5 planets of the ancients, and an immense swarm of smaller ones between the orbits of Mars and Jupiter. We also know that the sun is not a planet, but a fixed star, its change of place being only an apparent one, arising from our own daily change of place, as the earth proceeds forward around the sun.

The sun keeps the planets in its his neighborhood

by the superior attraction of its mass, which is several hundred times the combined masses of all the other bodies of the system. The sun is also distinguished by being self-luminous, while the planets and satellites are dark bodies which shine only by reflecting the solar light. These associated orbs, called the Solar System, are so bound together by the law of gravitation that each planet may make countless revolutions without changing the plan of the system. The symmetry of this plan is remarkable. This is shown by the fact that all the large planets and all the satellites revolve in orbits which are nearly circular, and, the satellites of Uranus and Neptune excepted, nearly in the same plane, and from west to east.

The dimensions of the solar system are inconceivably great; but dwindle down to insignificance when compared with the distances which separate the stars from each other.[a] Thus a voyager-

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[a] It is of very great interest to us all to know if the planets generally, either of our sun or of other suns, are peopled as is the earth. Of our own,

travelling nearly 32,000 miles a second, if this were possible, would be 39 hours in passing the distance from the sun to Neptune, but from 15 to 20 years in journeying beyond to the nearest star, and as many more years in passing to another. These enormous intervals place the stars practically beyond the reach of each other's gravitation, which

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we should most expect to find the planet Mars inhabited, from its apparent resemblance to the earth in many particulars. The surfaces of most of the other primary planets are apparently hidden from us by immense atmospheres, and the little we can see indicates a great variety of constitution. On the whole, it is not likely that any considerable fraction of the heavenly bodies are suited to the existence of such animals as live on the earth, while we may consider that a very small fraction indeed are adapted to the support of civilized life. This fraction, however, may really include a very large number, of which many may be peopled by beings of a much higher intellectual order than ourselves. Further, it is not improbable that every orb has

the stability of the system is insured for a very long period of time, though not probably for an endless one.

The bodies of the Solar System vary enormously in size, distance, and mass, making it difficult to lay down a map of the whole system on the same scale.

Apparent Motions of the Heavenly Bodies. The celestial sphere is the blue vault in which the sun, moon, and stars seem to be set, as they perform their motions above the horizon. If we watch the stars at the north for a night-time we shall find each one describing a circle around a fixed center called the Pole[a], the size of which circle

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its period of adaptation to organic life, which period may be but a small part of the whole interval of time during which the orb endures.

[a] The Celestial Pole is the vanishing point of the parallel lines along which the axis of the earth is carried during its revolution in its orbit. Seen from the starry sphere, the earth's orbit must therefore be likewise reduced to a point (See p. 15). A system of

depends on the distance of the body from the Pole. This distance at length becomes so great that the revolving star describes a part of its circle below the horizon and is then said to rise and set. Stars 90° from the Pole, or those situated on the equator, describe one half of their diurnal circles below the horizon. Stars more than 90° from the North Pole revolve around the South Pole, describing smaller and smaller circles the nearer they are situated to this Pole. Thus the whole sphere seems to revolve daily around an axis passing through the centre of the earth. We know that this motion is only apparent, arising from the rotation of the earth on its axis, and consequently performed oppositely to the direction of this rotation, or from east to west. The direction of the motion, looking towards the north, is contrary to that in which the hands of a clock move. The circle at the north within which the stars never set, in our latitude, is called the circle of perpetual apparition. A circle corresponding to this

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railroad tracks extending for a considerable length in a straight direction furnish a familiar example of the effect of distance upon parallel lines.

at the south, within which the stars never rise, is called the circle of <u>perpetual disappearance</u>. The stars within these two circles are called <u>circumpolar</u>, the <u>northern</u> and the <u>southern</u>. The voyager going south sees the Pole Star ($1\frac{1}{2}°$ from the Pole) sink lower and lower until, at the equator, the two Poles of the celestial sphere lie in the horizon, and all the stars describe half-circles above and below the horizon.

The altitude of the Pole is equal to the latitude of the place. In middle latitudes therefore, as with us, the Pole is about half way between the horizon and the zenith. Stars which never set are seen to cross the meridian both <u>above</u> and <u>below</u> the Pole. The former passage is called the <u>upper culmination</u> and the latter the <u>lower</u> one.

Whenever the Pole is above the horizon of an observer, this circle divides the diurnal circles described by the heavenly bodies, the equator excepted, into two unequal arcs. North of the equator, the greater arcs of northern diurnal circles and lesser arcs of southern ones lie above the horizon, and the reverse south of the equator. Hence it is that the sun's course exceeds 12 hours during 6 months of the year, and the sun's

during half of every revolution. Hence also the stars which unlike the sun and moon always preserve the same latitude, make a wide circuit of our sky, if northern ones, but soon cross it, like red Antares, if southern ones. The greater the latitude of the observer, the more unequally are the diurnal circles divided by his horizon, and therefore the greater the difference between the length of his days and his nights, whenever the sun is not vertical to the equator (See "Day and Night" p.)

The sun comes to the meridian every day about a degree east of the place it occupied in the celestial sphere the day before. We know this from the fact that new stars lie on the meridian every midnight; these being always 1° east of those occupying it 24 hours before. The sun therefore performs an apparent revolution among the stars every year, which revolution is due to the annual motion of the earth in its orbit.[a]

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[a] The young student will see why the sun should appear to describe a circle in consequence of the earth's annual motion if he will walk around any prominent object in the landscape, as a tree on a hilltop, and observe how the tree appears to move around the

The apparent path which the sun describes in this revolution is called the ecliptic. (See p.) The two points in which the ecliptic crosses the celestial equator are called the equinoxes, the vernal and the autumnal. The two points at which it is most distant from the celestial equator are called the solstices, the summer and the winter.

The longitude of heavenly bodies is reckoned on the ecliptic, beginning at the vernal equinox. Since the sun moves along this circle at the rate of about 1° a day, its longitude may be known at any time by ascertaining how many days have passed since its passage of the vernal equinox on Mar. 20. Or more simply, the sun's longitude is 0° on Mar. 20, 90° on June 20, 180° on Sept. 20 and 270° on Dec. 20, or about these dates. Its longitude

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horizon in the course of his walk. The earth's daily motion may be illustrated at the same time if the person will turn himself around, say once every fourth of the distance, and observe how the tree alternately disappears and reappears, showing the daily rising and setting of the heavenly bodies.

[illegible] the inequalities in
[illegible] right ascension,
[illegible]
[illegible]
[illegible]
[illegible] 113,
[illegible] 17 [illegible]

any intervening date may therefore be found by correctly increasing these longitudes according to the number of days which have passed since that date.

The Moon's Motion. The moon performs a revolution around the celestial sphere in 27 days and 8 hours,[a] but requires more than 2 days longer to complete her phases. This is because the earth is moving in the same direction as the moon, so that the latter has more than a complete revolution to perform before the three bodies are again in line, as at the new moon. The interval from new moon to new moon (29½ days) constitutes the lunar month. This interval is also called a lunation. Owing to the motion of the moon's nodes (See p. [illegible]) the moon describes a slightly different path every month.

Eclipses of the Sun and Moon. Whenever the moon is situated between the earth and the sun, as happens occasionally at new moon, she conceals the whole or a portion of the sun's disk, thereby causing a solar eclipse. Again, whenever the earth is situated between the sun and the moon, as happens occasionally at full moon, the

[a] For the manner in which this revolution is performed, see page [illegible] with the accompanying figure.

(ac the sun p. . These transits occur 4 times every 243 years,
at intervals of 105½, 8, 121½, and 8 years.[c] During the short intervals Venus is near the two opposite points in which her orbit intersects the earth's (her nodes), and during the long intervals she is describing the two arcs remote from these points, and is therefore either above or below the sun when in inferior conjunction,

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[a] The apparent or synodic period of Venus is 584 days; the planet is therefore seen as a morning star (east of the sun) for between 9 and 10 months, and then as an evening star (west of the sun) for the same interval. Her true or sidereal period is 224.70 days.

[b] This orbit is nearer a circle than that of any other of the large planets.

[c] Venus makes 13 revolutions around the sun while the earth makes 8, and hence this interval.

earth casts a shadow on the moon, thereby causing a <u>lunar eclipse</u>.

If the moon revolved in the plane of the ecliptic, there would necessarily be an eclipse of the sun every new moon, and an eclipse of the moon every full moon. That such is not the case is due to the inclination of the lunar orbit to the ecliptic (See "The Moon" p.) whereby the moon generally passes above or below the sun at conjunction, and above or below the earth's shadow at opposition. Every time the sun is in the neighborhood of the moon's node, however, and it crosses both nodes yearly, the moon is sure to intercept him on one side or other of the node, and hence there must be at least two solar eclipses every year to some points of the earth's surface.

The moon is very much smaller than the sun, but so much nearer that she appears to be almost of the same size. Owing to the elliptical form of her orbit, however, her distance from the earth, and hence her apparent diameter varies. When her disk entirely covers the sun, the eclipse is <u>total</u>; when it leaves the outer part of the solar disk exposed to view, forming a ring around the moon, the eclipse is <u>annular</u>; when it overlaps a greater or less portion of one side of the sun, the eclipse is <u>partial</u>.

We have seen that lunar eclipses occur at full moon, and are caused by the moon's passing through the earth's shadow. This shadow, at the distance of the moon, is much smaller than the earth itself[a]; and

~~As the last streak of sunlight is disappearing, in the case of a total or annular eclipse of the sun, it is broken up into a number of points, caused by the sun's shining through the depressions between the lunar mountains. These points are known as "Baily's beads", from the observer who first described them.~~ ;

;[a]

Since the sun is larger than the earth and moon, their shadows terminate in a point, forming a cone called the _umbra_. Further, a portion of the light from the right side of the sun is cut off at the left side of the moon, and from the left side of the sun at the right side of the moon, forming a divergent space of fainter shadow on each side of the umbra, called the _penumbra_. These two parts may be readily seen by holding a marble or other small sphere close to the flame of a lamp, and receiving its shadow upon a sheet of paper. To succeed in this experiment, the diameter of the sphere should be considerably less than the width of the flame and should be held central to it. There should also be but one light in the room. (See "Cones of Penumbrae", Nat. Phil.)

The moon very rarely becomes invisible in a total eclipse, but assumes a dull coppery hue, which is sometimes so vivid as to allow the spots on its surface to be distinctly seen. This appearance is due to the refraction of the sun's rays in passing through the earth's atmosphere.

is in the region of Aries, the times
setting compare similarly for the
ars from Mar. 1 to Apr. 10 there is a
~~in the time of sunrise and~~ of 45 m
unset; while from Sept 1 to Oct 10,
the region of Libra, there is a
in the time of sunrise, and of 1 h
sunset. (See Almanac.)

the moon must therefore be very near to her node in order to strike the shadow, whose centre is at the node. Sometimes a whole year passes without a lunar eclipse.

Lunar eclipses may be either <u>total</u> or <u>partial</u>, but they are never annular for the reason that the eclipsing shadow is always much broader than the lunar diameter. (See end of P on fly leaf.)

A solar eclipse is visible from only a part of the hemisphere which has the sun above the horizon, and at different stations successively; while a lunar eclipse is visible from every part of the hemisphere which has the moon above the horizon, and everywhere begins and ends at the same instant. This difference is due to the fact that the sun's disk is not really darkened in a solar eclipse, but only hidden behind the moon, so that the interposition varies according to the respective positions of the observer, the moon, and the sun. In a lunar eclipse, on the contrary, the moon's light is really extinguished, and hence the obscuration must be apparent everywhere the moon is in view, and during the same interval of time.

Quite remarkably, 223 lunations occupy the same interval of time, within a few hours, as 19 synodical revolutions of the lunar node, or 18 years and 10 days.[a] This causes the phenomena of eclipses to return in the same order with the recurrence of the interval thus defined, and also furnishes a starting-point for the calculation of eclipses. This period was discovered many ages before the exact <u>theory of eclipses was understood.</u>

[a] This period divided by 19 shows the season of eclipses to be about 20 days earlier each year.

Time. The astronomical divisions of time are the day, the month, and the year.

A sidereal day is the interval of time between two successive transits of a star, or the period in which the earth makes one revolution on its axis. The duration of the sidereal day is $23^h 56^m 4^s.09$.[a]

A solar day is the interval of time between two successive transits of the sun over the same meridian. This interval would always be of the same length, by reason of the sun's moving uniformly around the sky, if the earth's orbit were a circle and the ecliptic coincided with the equinoctial. The facts of the case being otherwise, as we know, the actual solar day is never two days in succession of the same length. The civil, or mean solar day is the average of all the solar days in the year. It commences at midnight and consists of 24 hours or two periods of 12 hours each, as reckoned.[b]

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[a] The transits of the vernal equinox are ~~always~~ employed to mark the beginning and end of the sidereal day. This day is reckoned in every observatory by a clock which shows $0^h 0^m 0^s$ when the equinox passes the meridian.

[b] The difference of about 4 minutes between the solar and the sidereal day is owing to the eastward motion of the earth in its orbit, in consequence of

The time of day indicated by the sun in its irregular motion across the sky is called Apparent Time. The time which would follow from a uniform solar motion, or that shown by a correct clock, is called Mean Time. Apparent and mean time differ the most on Feb. 10, when the sun is 15 minutes behind the clock, and on Nov. 2, when the sun is 16 minutes ahead of the clock. Apparent and mean time coincide on Apr. 15, June 14, Aug. 31, and Dec. 24.[a]

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which it must perform more than a rotation before the same meridian returns to the sun. Thus it follows that the number of solar days in the year is one less than the number of sidereal days.

[a] The recent change of time made at the instance of the railway corporations limits this adjustment of mean to solar time in the United States to 4 governing meridians, the 75th, 90th, 105th, and 120th, these meridians lying midway of the sections adopting their respective time. It is thus arranged that there shall be four differences of time from the eastern to the western seaboard, instead of a difference with every movement of longitude as heretofore.

$365^d 5^h 48^m 47.^s7$

The number of days in the year being too great for convenient reckoning, an intermediate measure was suggested by the phases of the moon. The lunar month not being an exact division of the year, however, after much consequent confusion of the ancient calendars, the lengths of the months were finally arranged as we now have them.

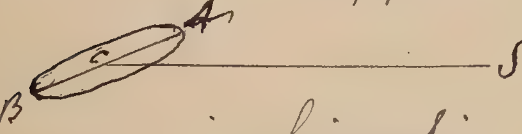
The last, or Gregorian reformation of the calendar, was made in order to restore the vernal equinox to its position at the time of the Council of Nice. Hitherto, for 16 centuries, the calendar year had been reckoned 11¼ minutes longer than the solar year, which had finally brought the equinox on the 10th instead of the 21st of March. It had also brought Easter the same amount out of place, the latter being the real cause of the change directed by Gregory.

The length of the mean Gregorian year is $365^d 5^h 49^m 12^s$. This is still 26 seconds longer than the tropical year, an error which will not amount to an entire day for more than 3000 years.

Precession of the Equinoxes.

This consists in a very slow revolution of the equinoctial points westward along the ecliptic, with a corresponding revolution of the pole of the equator around the pole of the ecliptic.[a] The cause of precession was a mystery for more than 18 centuries, or from the time of its discovery by Hipparchus until the discovery of universal gravitation by Newton. The latter was then enabled to explain that the revolution in question was produced by the attraction of the sun and moon upon the protuberance at the equator of the earth.

Suppose the circle AB, Fig. to represent this



protuberance at its greatest inclination to the sun, as at the solstices. Here the sun at S obviously attracts the nearer point A towards the plane of the ecliptic more than it attracts

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[a] The assertion is evidently true of both poles, but it is customary to use this word in the singular.

The poles of the ecliptic are two opposite points in the centres of the two hemispheres into which the ecliptic divides the celestial sphere.

the farther point B from the plane of the ecliptic, while the centrifugal force generated by the revolution of the earth in its orbit is less at A than at B. This difference of action upon A and B would gradually bring the line AcB into coincidence with the line cS, or the plane of the earth's equator would ultimately lie in the plane of the ecliptic. But this effect is prevented by the rotation of the earth, so that, instead of a motion of AcB to cS, a very slow motion of the equator at right angles to the direction of the former motion is produced, which constitutes the motion of precession. Just so the spinning of a top causes the top to wabble after it has begun to lean, and it would continue to operate thus if the speed of the top were not diminishing.

The motion of the equator in precession is attended by a conical motion of the axis of the earth, in which the poles describe circles around the extremities of a diameter of the earth perpendicular to the earth's orbit, and having therefore a radius equal to the inclination of the axis to the orbit, or 23½°. This causes the pole of the celestial

equator (See p. a) to describe an apparent circle of the same radius around the pole of the ecliptic.[a]

The rate of precession is nearly a degree in 70 years, showing the entire circuit to be performed in about 25,000 years.

When the sun is on the equator, as at the equinoxes, it cannot produce precession because the points A & B (Fig.) then lie in the plane of the ecliptic. At other times, precession is greatest at the solstices, and still greater at the winter than at the summer solstice, because the

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[a] The motion of precession may be illustrated in this way: Sink a stick half-way through a small circle of paper, and placing the stick slantwise in a tumbler, turn it so as to carry the ends around the top and bottom of the tumbler. These ends will then describe circles around the centres of the top and bottom similar to those which the poles of the celestial equator describe around the poles of the ecliptic because of precession. At the same time two opposite points in the circumference of the paper will travel midway around the tumbler, showing the revolution of the equinoctial points. The student should remember how slowly the axis turns, in the earth's case.)

earth is nearer to the sun in Dec. than in June.

The principal part of precession is produced by the moon on account of her greater proximity to us[a]. Lunar precession is variable, as has been shown of solar precession, and for the same causes. There is, besides, the additional cause that, owing to the revolution of the moon's nodes, the inclination of the moon's orbit to the plane of the earth's equator is subject to an oscillation having a period of about 19 years (See "The Moon" p. a), producing an inequality of the same period in the precession[b]. The several

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[a] Precession is produced by the difference of the attractions on the two sides of the earth; hence, although the attractive force of the sun upon the earth is more than 100 times that of the moon, the difference mentioned above is 3 times as great in the case of the moon as in that of the sun.

[b] When the moon's orbit is at its greatest inclination to the earth's equator ($28\frac{1}{2}°$) the moon's force to tilt the earth is great, and the precession goes on rapidly. When the moon's orbit is at its least inclination to the earth's equator ($18\frac{1}{2}°$) the moon's force to tilt the earth

inequalities in precession which have been described are known as nutation of the earth's axis.

A change in the place of the celestial pole and vernal equinox changes the declination and right

is small, and the precession goes on slowly. This action of the moon upon the earth, if subsisting alone, would cause the pole to describe a minute ellipse among the stars every 19 years, but since it is carried forward at the same time by the greater and regularly progressive motion of precession, the path which it pursues in virtue of the two motions is a gently undulated circle.

The revolution of the lunar nodes is produced in a way exactly similar to that of precession. Thus in Fig. , A representing the moon's place when nearest to the sun, where the centrifugal force generated by its revolution around the sun is therefore at its least value, and B representing the moon's place where farthest from the sun, where the centrifugal force is therefore at its greatest value, the effect of the sun's attraction upon A, drawing it towards the plane of the ecliptic, is greater than its effect upon B, drawing it from the plane of the ecliptic. This difference of effect would ultimately bring the moon into the plane of the ecliptic but for

ascension of the heavenly bodies, and hence precession destroys the arrangement of star-catalogues after certain intervals, and makes it necessary to reconstruct them.[a]

The Tides.

The relation between the moon and the tides was perceived in very remote ages, but it was not explained until after the discovery of gravitation. This force, which, as we have seen (p. 13), belongs to all matter, decreases as the square of the distance between any two bodies, or any two parts of the same

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her revolution in her orbit. This revolution, acting against the pull of the sun, causes the moon instead to cross the ecliptic sooner (below A, later but less so above B) than if such pull were wanting, and thus the moon's nodes are gradually carried westward around the entire ecliptic. The sun, earth, and moon, acting and reacting upon each other, furnish a problem of great difficulty, distinguished by the name of the problem of the 3 bodies.

[a] It was this disagreement between the recorded and the actual places of stars that led to the discovery of the precession of the equinoxes.

body, increases. It follows, therefore, in the case of the tides, that the water on the side of the earth next the moon is more attracted by the moon than the solid body of the earth, and hence rises; while the water on the side opposite the moon is less attracted than the solid body of the earth, and hence left in a heap behind.[a]

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[a] The inequality of the moon's attraction on the water and the solid body of the earth being nearly the same on both sides of the earth, it follows that there would be no appreciable difference in the height of the two opposite tides. The earth's revolution about a centre of gravity 1000 miles below its surface (See p.) helps somewhat to heap up the water on the side opposite the moon, such a revolution converting a flexible globe into an egg-shaped body.

The great wave which constitutes the tide is to be considered as an undulation of the waters of the ocean, in which (except when it passes over shallows or approaches the shores) there is little or no *progressive* motion of the water. (Loomis.)

The moon must also cause similar, though very minute tides in the atmosphere, and there is reason to believe that its attraction may affect the occurrence of earthquakes. (Newcomb.)

As the rotation of the earth brings every place upon its surface alternately into the moon's longitude (the moon being therefore above the horizon), and into the opposite longitude (the moon being therefore below the horizon) every 12½ hours nearly[a], it follows that tides generally occur at intervals of this length.

As a consequence of the massing of the waters of the ocean on two opposite parts of the earth's surface, the waters everywhere 90° distant, or where the moon appears in the horizon, are the lowest. At such places, therefore, it is ebb or low water.

The greater the moon's meridian altitude is at any place, the higher the tides will be, for they increase from the horizon to the point under the zenith; and the greater the moon's depression is below the horizon, the higher the tides will be, for they increase from the horizon towards the point below the nadir.

The crests of the two tidal waves on the earth's surface being always diametrically opposite to each other, it follows that when the moon has declination, the two daily tides at places removed from the equator will not be of the same height. Thus, if the moon is 10°

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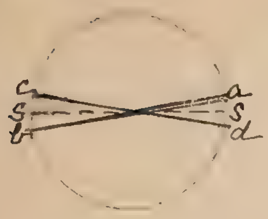
[a] See p. "The Moon's Motion", last paragraph.

north of the equator, with the crests of the two tidal



waves consequently at 10° N. latitude and 10° S., (a and b of the figure), places in 10° N. latitude will be in line with the former, but 20° north of the latter, as at c. This difference in the height of the two daily tides is called the <u>diurnal inequality</u>, because its cycle is one day; but by reason of counteracting agencies it varies greatly.[a] It is the greatest with the moon at her greatest declination, and at the full. There is obviously no diurnal inequality at places situated on the equator, and none anywhere when the moon is vertical at the equator.

In the winter, at new and full moon, the tidal wave at the nadir is in north latitude, and in the summer the tidal wave at the zenith is in north latitude; hence the tide following midnight is the highest in winter, and that following noon the highest in summer. The same statement is true of the southern hemisphere, substituting south latitude for north.

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[a] Along the Atlantic coast of the United States, when the moon has its greatest declination, the difference between high water in the forenoon and afternoon averages about 18 inches.

Since the moon's meridian altitude decreases from the tropics towards the poles, the tides also decrease in height in the same direction. With the moon in the equator, it will be low water at the poles during the whole day.

Owing to the inertia of the water, the crest of the tide is some hours behind the moon's place. For the same reason, the highest tides (See further) far 30 hours behind full and new moon, and the lowest the same amount behind the quadratures. The coast-line, by its interference, may also delay the tidal wave many hours, or even a whole day. Two tidal waves meeting each other, or the motion of a long mass of water, as in a long bay, will raise an enormous tide. In the Bay of Fundy both these causes are combined, forcing the water at the head of the Bay to the height of 60 or 70 feet. Many other influences greatly complicate the tides in various parts.[a]

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[a] "The tidal wave extends to the bottom of the ocean, and moves uniformly and with great speed in very deep water, variably and slow in shallow water. A tide is sometimes impeded by an obstacle (the form of the coast, or some irregularity of the bottom of the sea) until

The sun produces a tide as well as the moon.[a] At new and full moon the attractions of the two bodies are united, giving us the spring-tides.[b] When the moon

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a second tide reaches the same point by a different course, and the water rises to double the height it would otherwise have attained. A complete extinction of the tide takes place when a high water interferes in the same manner with a low water. When two unequal tides of contrary phases meet, the greater overpowers the lesser, and the resulting height is equal to their difference; such varieties occur chiefly in channels, among islands and at the estuaries of rivers." Phy. Geog. by Mary Somerville.

In mid-ocean the average height of the tides does not exceed 3½ feet; the average in the neighborhood of continents is from 4 to 5 feet.

[a] The inequality of its attraction upon the water and the solid body of the earth, and hence its tide-producing force, is about 2/5 of that of the moon.

[b] The sun attracts the moon more than the earth when the moon is new, and the earth more than the moon when the latter is full, tending to increase the distance between the two bodies in both cases. In the

is in her quarters, or 90° from the sun, the two bodies act against each other, giving us the neap-tides. The highest spring-tides of all occur when the moon and sun are both in the equator. These are the equinoctial spring-tides. They are owing to the fact that the tidal wave, moving around the equator, describes a greater circle than at any other times of the year, and as this circle is described in the same time that a less circle is discribed, the waters are thrown more forcibly against the shores in the former case than in the latter. The equinoctial spring tides are also greater from the fact that the moon and sun are nearest to the surface of the earth, when in the equator.[a]

The extent of the tidal circuit and distance of the attracting bodies from the earth's surface thus affecting the height of the tides, it is obvious that the smallest spring-tides take place at the

former case the effect produced is the greatest, because the moon when new is nearer the sun than the earth (the moon being full), and hence the full-moon spring-tides are higher than the new.

[a] The tides are the highest when the moon passes the meridian about an hour after the sun, for then the maximum effect of the two bodies coincide.

solstices, if the moon, as well as sun, is situated upon a tropic.

At the solstices the moon, when in quadrature, is situated on or near the equator; at the equinoxes, when it is in quadrature, it is situated on or near a tropic; in the former case the difference between the solar and the lunar tide is greater than in the latter case, and hence the solstitial neap-tides are greater than the equinoctial.

The distances of the sun and moon from the earth also influence the height of the tides. Other things being equal, the height of the tide is proportionality greater as the two bodies are nearer the earth. Thus, the tides of the winter solstice are higher than those of the summer one. The tides are likewise higher with the moon in perigee than, under similar circumstances, at other time.

The tides are affected by the state of the atmosphere; thus at the London Docks, a fall of 1/10 of an inch corresponds to a rise in the Thames of about 7/10 of an inch. The tide is also liable to be disturbed by winds.

Since the tide-crest, following the moon, moves westward, all eastern shores have far greater tides than western; thus the

In the first and third quarters of the moon, the solar tide is westward of the lunar one, and, consequently, the actual high water, which results from the combination of the two waves, will be west of the place it would have if the moon acted alone, and the time of high water will therefore be accelerated. In the second and fourth quarters, the solar tide being now east of the lunar, there is a retardation in the time of high water.[a] These changes in the time of high water are commonly calling the *priming* and *lagging* of the tides. In consequence, the interval between the consecutive tides is the least (12 h 19 m) near the time of new and full moon, and the greatest (12 h 30 m) near the quadratures.

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[a] In fig. the solar tides ss are shown to be west of the lunar tides c d and east of the lunar tides c d.

"The instant of low water is not at the mid-interval which separates two consecutive flood-tides, the flow being of much shorter length than the ebb, or, in other words, the sea takes longer to go down than to rise. This difference varies according to the ports; thus, it is 16 m. only at Brest, and at Havre 1 h. 16 m." [illegible]

Chapter. V
The Planets. ~~Mercury, Venus The Earth.~~

Mercury.

Mercury is the nearest known planet to the sun and the smallest of the eight large planets, its volume being less than one-eighth of the earth's. When visible, it appears as a brilliant, twinkling star in the faint glimmer of morning or evening twilight. The scintillation, which none of the other planets exhibit, or very slightly, is caused by its intense radiance, owing to the sun's proximity, and by the fact that it is never seen except when near the horizon. For these reasons also, it cannot be examined with a telescope, and hence nothing is known certainly of its rotation or physical constitution.

As Mercury is an inferior planet, its track in the sky is limited to a certain arc which it describes alternately on each side of the sun.[a]

[a] To the young student. A person walking around a tree at a distance of 30 feet from it, would s

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When at its greatest distance east or west of the sun, which, owing to the great eccentricity of its orbit,[a] varies from 18° to 28°, it is said to be in its greatest eastern or western elongation. It is only visible at or near these times,[b] as it is obscured in the brightness of the dawn or sunset when nearer to the sun. The best time for observing it is in the evening twilight, about three quarters of an hour after sunset. The spring is more favorable for this than the autumn. Mercury is generally visible for 15 or 20 days at a time.

As the planets, like the earth, have a dark

one 10 feet from it, when farthest to the right or the left, about 19° from the tree, as measured on the horizon. On the other hand, the inner person would see the outer one move to a distance of 180° from the tree. This may illustrate the difference in the motions of the inferior and the superior planets.

[a] This orbit differs more from a circle than that of any of the large planets.

[b] These happens at intervals of about two months. Mercury's period is 88 days, but as the earth advances around the sun at the same time with Mercury, the apparent period of Mercury, called its _synodic_, is 116 days.

half turned from the sun, it follows that the two moving between the earth and sun, Mercury and Venus, must sometimes present their dark portions more or less to the earth, as the moon does. Thus Mercury is "new" when between the earth and the sun, or in inferior conjunction, as it is called; "full" when beyond the sun, or in superior conjunction, and a half-planet midway of these positions on each side of the sun. When nearly new, the apparent diameter of the thin crescent then visible through a telescope, is more than twice that of its full phase in the opposite part of its orbit.

Transits of Mercury across the face of the sun are always looked upon with great interest by astronomers. These transits are much more frequent than those of Venus.

Venus.

Venus moves around the sun about half-way between the orbits of Mercury and the earth, and is very nearly the size of the earth. Next to the sun and moon, Venus is the most brilliant object in the heavens, sometimes casting a distinct shadow, and even visible in the daytime when it is the

brightest,[a] or about 40° from the sun. It is pretty certain that a dense covering of clouds hides the solid body of Venus from sight, making it difficult of examination,[a, b] and that these clouds are suspended in an

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[a] The light of all the planets varies during their revolution, on account of their varying distances from the earth in different parts of their orbit. The distances of the inferior planets from us when on the same side of the sun, and when on the opposite side, differ the diameter of their orbits; the distances of the superior planets, at the same positions, differ the diameter of the earth's orbit. There is an important difference in the situation of the inferior and the superior planets, regarding the sun as seen from the earth, when in the positions mentioned: the inferior planets, in both positions, are in conjunction with the sun, distinguished as the inferior and the superior conjunction, as already mentioned; the superior planets, when on the opposite side of the sun from the earth, are in conjunction with the sun, and when on the same side of the sun as the earth, are in opposition to the sun, or 180° distant.

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atmosphere[b] similar to our own.

As Venus, like Mercury, is an inferior planet, its track in the sky is also limited to a certain arc which it describes alternately on each side of the sun.[c]

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[a] This is also the case with all of the superior planets excepting Mars; but the parallel streaks seen on some of them probably indicate the position of their equators.

Prof. Young says in his address entitled "Pending Problems of Astronomy": "With Venus the state of things is a little better" (than with Mercury); "we do already know, with some degree of approximation, her period of rotation ($23^h 21^m$), and the observations of the last few months bid fair, if followed up, to determine the position of her poles, and possibly to give us some knowledge of her mountains, continents, and seas."

[b] When Venus shows as a thin crescent, this atmosphere is indicated by the illumination of the dark limb of the planet, so that it appears as a complete circle of light.

[c] The apparent or synodic period of Venus is 584 days; the planet is therefore seen as a morning star (east of the sun) for between 9 and 10 months, and then as an evening star (west of the sun) for the same interval. Her true or sidereal period is 224.70 days.

The length of this arc, or the greatest elongation of Venus is about 45°, and therefore Venus never rises earlier than three hours before sunrise, or sets later than three hours after sunset. The diameter of the orbit of Venus[a] being greater than that of Mercury, her distance from the earth, and consequently her apparent diameter, has a greater variation. In the case of the diameter, this is apparently more than 6 times as great when Venus is the nearest than when she is the farthest. This planet is a very beautiful object for telescopic observation, but, owing to its extreme brightness, a very difficult one.

Venus is celebrated for its transits across the sun, which afford a good opportunity for measuring the sun's distance (See "The Sun" p.). These transits occur 4 times every 243 years, at intervals of 105½, 8, 121½, and 8 years.[b] During the short intervals Venus is near the two opposite points in which her orbit intersects the earth's (her nodes), and during the long intervals she is describing the two arcs remote from these points, and is therefore either above or below the sun when in inferior conjunction.

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[a] His orbit is nearer a circle than that of any other of the large planets.

[b] Venus makes 13 revolutions around the sun while the earth makes 8, which accounts for this interval.

[a] The best time to see one of the outer planets is when it is in opposition to the sun, at which time it rises about sunset. The best time to see one of the inner planets is when it has its greatest elongation. A star map showing the position of the ecliptic among the stars, will assist in finding the planets, which are always very near the ecliptic.

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Mars.

Mars is the 4th planet in the order of distance from the sun, and the next one outside the orbit of the earth. Being a superior planet, it removes to a distance of 180° from the sun in the course of a revolution (See a p.), and is then said to be in opposition, as already mentioned. At times of opposition it comes to the meridian at midnight. (See a on fly leaf.) But because of the eccentricity of its orbit, in any part of which opposition may take place, Mars is much nearer to the earth and therefore much more brilliant at some oppositions than at others. The apparent diameter of Mars varies from 4" to more than 25" during a revolution.

Next to Mercury, Mars is the smallest of the primary planets, its diameter being little more than 4000 miles, and its volume 1/7 of the earth's. Mars may be known by its ruddy color, which has been accounted for in several ways.[b] The light of Mars is generally

[b] "Mr. Lockyer suggests that the red color of Mars may depend upon the cloudy state of the planet, the planet absorbing more light than the clouds, and on

steady, and it is thus, like the other planets, distinguished from the stars of the same apparent magnitude. Mars can never appear horned or even half-mooned, because its path lies outside the earth's, but it presents a full disc only at opposition and conjunction. In every other part of its orbit it is more or less gibbous and perceptibly so about half-way between opposition and conjunction, or near its quadratures. Mars is the only planet whose surface is apparent, and this surface shows the distinct outlines of what may be continents and seas. Of these, the former have a ruddy look, and the latter a greenish, but the outlines are sometimes quite faint, as though they were obscured by clouds. Brilliant white spots are also seen around the poles, which dis-appear in great part during the polar summer, and are greatest when just emerging from the long night of the polar winter. The permanent markings seen on Mars show plainly

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one occasion the spectroscope indicated this increased absorption by revealing the fact that the sunlight was reflected to us <u>minus</u> a large portion of the blue rays." Guillemin.

its time of rotation, or the length of its day, which is about half an hour longer than ours. Its year is 687[a] of our days. Its equator is inclined 27° to the plane of its orbit, making the change of seasons somewhat greater than ours.

Mars has two diminutive moons, showing only as faint points of light in the telescope. The inner one is very remarkable in that it is less than 4000 miles from the surface of its primary and goes around it in 7h. 38m.[b], so that it passes through all its phases in a single night.

The Small Planets.

All these planets, numbering more than 200 as now known, are remarkable for their minuteness, the disks of the brightest of them presenting the appearance of mere stars, seen through the telescope. It is impossible, therefore, to measure their diameters,

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[a] See the "Table" p. for figures in general.

[b] A curious consequence of this period's being less than the day of the primary is that this moon, to the inhabitants of Mars, would seem to rise in the west and set in the east. Newcomb & Holden's Astron.

Our own moon moves from west to east in her orbit; if the rate of this motion exceeded the rate of the earth's rotation, she would also be seen traversing the sky from the western to the eastern horizon.

but these may be roughly estimated from the amount of light which they reflect. It is thus inferred that Ceres and Vesta are the largest of the group, with diameters lying somewhere between 200 and 400 miles, while the smallest are probably from 12 to 30 miles in diameter[a].

The small planets lie in a zone between Mars and Jupiter, and owing to the great inclination of their orbits to the ecliptic, occupy a much broader region of the heavens than the zodiac. These orbits also differ from those of the large planets in being generally much more eccentric, whereby their distance from the sun varies considerably during a revolution.

Before the discovery of any of these bodies, it was

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[a] These little masses would confer a surprising buoyancy upon objects on their surfaces. In fact, the smaller the world, the greater must be the object to have a constant weight everywhere, excepting the attracting body be enough denser to offset the decrease of the radius. Density being the same, gravity diminishes directly as the cubes of the radii, and increases inversely as the squares of the radii.

thought probable that a planet existed somewhere between Mars and Jupiter, on account of the great interval between these two planets, as compared with the intervals at which the other planets succeed each other.[a] An association of 24 astronomers was therefore formed, each of whom was to search through a 24th part of the zodiac, but before they got fairly to work

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[a] A planet is assigned its order of position from the sun by observing the apparent daily motion of the planet among the stars, the nearer moving the faster. In this way it has been learned that the zone of small planets occupies an interval between 30 and 40 millions of miles from the orbit of Mars on the inside, and 50 millions of miles from the orbit of Jupiter on the outside. Beyond certain limits the attraction of Mars or Jupiter would completely derange the orbit of any wandering orb, and hence the zone is fixed. Thus here, as everywhere throughout the heavens, are seen the effects of that wonderful force we call gravity, which, as Herschel remarks, it is but reasonable to regard as the result of a consciousness and a will existing somewhere, though beyond our power to trace.

the planet was accidentally discovered by an outside observer who named it Ceres. This was in Jan. 1801. In 1802 and '4 a second and a third planet were found revolving between Mars and Jupiter, a 4th and a 5th in 1807 and '45, and since the last named date as many as ten of these little worlds have sometimes been discovered in a year. In fact, their value to the astronomer is far below the labor of keeping them from being lost, and it has therefore been suggested that such of them as seem unimportant be again suffered to pursue their course unheeded by the telescopist and computer.

The periods[a] of the small planets vary from about 3 to 8 years.

Jupiter.

Jupiter is an enormous planet, being nearly 1300 times the size of our earth. It is easily known in the

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[a] The period of a planet is learned by noting the interval of time elapsing between the successive passages of the planet through the same node, ascending or descending, that is, in passing from the south to the north side of the ecliptic, or the reverse.

"The observations made here during the last 3 years confirm the statement that the changes in the disk of the planet (Jupiter) are slow and gradual."

"Work of the Dearborn Observatory"
Popular Science Monthly Feb. 1883 —

sky by its brilliancy, which is but little inferior to that of Venus. During the last few years Jupiter has been very carefully studied, and there are reasons for believing that it is not yet covered by a solid crust, but that a dense shell of vapors rests upon a white-hot interior of liquid or gas. Seen through a telescope of sufficient power, great numbers of stratified, cloud-like forms are observed to cross the planet in the same general direction. These forms change rapidly and are more or less visible over the whole surface, but they are most decided about the tropics. The color of the equatorial regions also varies, being often of a rosy tinge. Sometimes a dark spot[a] moves

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[a] On rather rare occasions the planet is dotted with a number of small, bright spots like satellites.

Between the summer of 1878 and fall of 1882 a very conspicuous red spot, some 30,000 miles long and 6000 miles broad, was seen daily traversing the planet at the south of the southern equatorial belt, and with a rate of motion different from that of some bright spots near the equator. It gave rise to much curious speculation, and has been followed by a change of not only the forms, but the colors of the belts and spots, greatly increasing the brilliancy of the disk.

steadily across the disk, reappearing at stated intervals, from which it has been pretty certainly determined that Jupiter turns on his axis in about 10 hours.[a] This high rate of speed, combined with the small density[b] of the planet, causes a difference of 5000 miles between the equatorial and the polar diameters, the flattening at the poles being very perceptible in the telescope. It has been suspected that Jupiter shines partly by his own light.

Jupiter has 4 moons which shine so inconstantly as to indicate that violent changes are taking place on their surfaces. These moons, ~~or~~ the 3 inner ones, are celebrated for making known the fact[c] that light takes time to travel.

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[a] "Recent observations and researches indicate that the equatorial regions of Jupiter rotate in less time, and with more irregularity than the others, thus showing still another analogy between that planet and the sun." Newcomb.

[b] This is less than 1/4 of the earth's, almost exactly the same as the sun's.

[c] This fact was learned thus: These 3 moons are eclipsed by the great body of Jupiter at every revolution, which happens quite often from their rapid motion. Now it was found by Roemer, a Danish astronomer, in attempting to improve the tables of his predecessors recording the times of occurrence of these eclipses, that these times did not agree with an equable motion of the satellites, an inequality which Roemer felt could not be real. Thus the eclipses

Jupiter and Saturn are celebrated for the complicated manner in which they act upon each other by their mutual attractions whenever they come into conjunction. This occurs every 20 years, at points in their orbits nearly 2/3 farther round than at the preceding conjunction. From this proportion it happens that one planet slowly changes the orbit or path of the other during 450 years, and then for 450 years the orbits slowly come back to the same thing again.

Saturn.

Saturn is more than 700 times as large as the earth, but owing to its small density, only about 90 times as heavy. In fact, Saturn's substance has but little over half the packing of Jupiter's, although Jupiter's is so loose that the planet would be shaken apart if its rate of rotation were 4 times faster.

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were constantly seen later as the earth receded from Jupiter in its annual motion, until, at its greatest distance from Jupiter, the times appeared to be 22 minutes late. Roemer therefore concluded that it took light 22 minutes to cross the orbit of the earth, which would give it a velocity of about 140,000 miles a second. More exact estimates show this result to be too small by about 5000 miles. Two methods of dealing with this problem, called Fizeau's and Foucault's, are exceedingly curious and ingenious. So delicate is Foucault's method that the millionth part of a second of time can be measured by it as accurately as a carpenter can measure the breadth of a board with his rule.

On the evening of Dec. 7, 1876, a brilliant white spot was seen on Saturn, as if an immense mass of white-hot matter had been thrown up from the interior, and by watching the motion of this spot across the disk, Saturn was concluded to revolve on his axis in 10h. and 14 m.

Saturn is difficult to study from its great distance, which is more than 9 times as far from the sun as the earth, but, like Jupiter, it is thought to be in a heated state, and perhaps hot enough to shine by its own light. The small density of these two planets also points to this condition.

Saturn's rings[a] render this planet the most remarkable in the solar system. These rings are generally thought to be formed by a cloud of meteors, or miniature moons, so crowded as to hide the intervals between them.[b] They rotate near the plane of Saturn's

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[a] The rings of Saturn were a great perplexity to the early telescopists. Galileo thought a small globe was attached to each side of Saturn, but after observing this triple world for a year or two, he was exceedingly perplexed to see it become a single round globe, like the other planets. He feared his telescope had deceived him, and was so annoyed, it is said, that he never again looked at Saturn.

[b] "It is now established beyond a reasonable doubt that each of the small particles composing the ring of Saturn revolves on its own account."

Newcomb and Holden's Astron.

equator[a], whose bulging regions are supposed to attract them to this part. These rings, seen edgewise, which happens twice in Saturn's year, are visible only in the most powerful telescopes as an exceedingly fine line of light stretching out on each side of the planet. This apparent width shows them not to exceed 250 miles in thickness.[b] 8 moons revolve around the ringed Saturn, and all except the outer, very nearly in the plane of the ring. Consequently, when the edge of the ring is turned towards the earth, these, in their orbital motion, are seen to run along the edge like beads on a string. The outer satellite is remarkable for being the brightest except one, when west of the planet, and as faint as the faintest when east of it.[c]

As Saturn revolves around the sun in its long year, which is equal to 29½ of ours, its rings tip to and from the sun just as do our northern and southern hemispheres, and for a similar reason. Their inclination to the orbit of Saturn is a little more, however, than that in the earth's case, being 27°. There are two periods in Saturn's year, therefore, corresponding to our winter and summer solstices, when the rings

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[a] The rings lie in the same plane, concentric to each other.

[b] The thickness of these rings is a matter of conjecture, for it is not possible to measure this, it is so minute. Mitchell.

Rings cut out of a large newspaper would have much the same proportion as those of Saturn. Newcomb & Holden's Astron.

[c] The cause of this change is not known.

are seen from the sun, and also from the earth[a], at their full inclination of 27°. This is mostly the case between the years 1881 and 1889, while Saturn also passes his perihelion and the point of greatest declination within the same interval. The finest telescopic views of Saturn may therefore be obtained during this interval.

Saturn's light is of a dull yellowish hue, and generally equal to that of a moderate 1st magnitude star, from which it differs, however, in being remarkably steady. Saturn is about 2½ years in passing through a constellation of the zodiac. It is now in the constellation Taurus.

Uranus.

Uranus is 64 times larger than our earth and almost 15 times as heavy,[b] with a density a little below that of

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[a] Jupiter, Saturn, and Uranus always appear full to the earth, showing that we see them nearly as from the sun, and that therefore the earth is comparatively near to the centre of their orbits. That is, our great distance from the sun is almost nothing to the great distance of these planets from the sun. Neither, when in the direction of the sun, are they ever seen to transit his disk, and hence we know them to be exterior to the earth. (See "Mercury", p. , [a] for another ~~proof of this~~.)

[b] ~~In the case~~ The mass of planets ~~which~~ having satellites, ~~their mass~~ is deduced from the movements of the satellites. In the case of planets without satellites, their mass is deduced with ~~equal precision~~ from the influence of their masses on the other planets (sometimes a comet), or the perturbations which they cause in their movements.

Jupiter's. This planet is too far away to show any markings or changes on its disk, but is of a uniform sea-green color as seen in a large telescope. It was discovered by Sir Wm. Herschel one March evening in 1781, while he was exploring the constellation of the Twins. Previous to this time Saturn was supposed to be the outermost planet of the system, this planet and those interior to it having been recognized as wandering bodies from the earliest ages. (See p. .)

Uranus shines as a star of the 6th magnitude, and may therefore be seen without a telescope if one knows where to look for it. The year of Uranus is a long one, being equal to 84 of ours, during which it describes a much larger orbit than the earth at the much slower rate of 4⅕ miles a second. Should this rate be increased to 6 miles a second, Uranus would leave the sun forever, so enfeebled is the solar attraction at the great distance of this member of the system.[a]

Uranus has 4 moons, of which the two inner ones have only certainly been seen through a few of the most powerful telescopes in existence. Rather curiously, the moons of Uranus move from east to west in their orbits, instead of from west to east like the moons of the earth, Mars, Jupiter, and Saturn. They differ markedly from the latter also in following orbits which are nearly

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[a] The fall of a planet to the sun and the planet's velocity are adjusted to balance each other, just as the velocity with which a stone is whirled at the end of a string, must be more or less rapid according to the weight of the stone.

perpendicular to the orbit of their primary. A reference to star-maps showed that Uranus, previous to its discovery, had been seen and recorded on several occasions as an unnamed star of the constellation in which it chanced to be at the time, without a suspicion of its being a planet.

Neptune.

Neptune is 82 times as large as our earth and nearly 17 times as heavy. It is therefore 1/5 as dense, or ~~has~~ about ~~the density of~~ as dense as water. Seen through a large telescope, when the atmosphere is very fine, Neptune shows a round disk about 3" in diameter, and of a pale-blue color. Neptune has one moon, a minute object even in the most powerful telescopes. Its motion in its orbit is retrograde, or from east to west, like the moons of Uranus. Neptune is noted for the manner in which it was discovered. The planets attract each other slightly out of their direct paths, and it had been noticed for many years that Uranus was disturbed in a way not to be accounted for. This led to the conclusion that a planet existed outside the orbit of Uranus, and so truly was its place calculated from its effect upon Uranus, that it was found within a degree's distance. Like Uranus, Neptune had been seen before, and taken for a star. Its discovery as a planet was in 1846.

The Earth.

Our earth is the 3d planet in the order of distance from the sun. It is slightly larger than Venus, and 5 times as large as the combined masses of Mercury and Mars. Its distance from the sun varies, in different parts of its orbit, from 91 to 94 millions of miles, allowing for an uncertainty of several hundred thousand in the figures.

Externally, as we know, the earth is composed of land and water, with an invisible fluid part called the atmosphere resting upon its visible surface. But whenever we descend into its solid part we find a constant increase of heat[a] the lower we proceed, which makes it nearly certain that it is red hot at a distance of 12 miles down, and at a distance of 100 miles hot enough to melt most of the materials which form its solid crust. Hence many think that the interior is in a molten state, while there are several phenomena which seem to contradict this, as the tides for instance. For if only a crust lay between the ocean and the liquid interior, the whole earth would be drawn out into an ellipsoidal form by the attraction of the sun and moon, and land and water moving together, we could see no tides at all. Yet those who believe for this and other reasons, that the earth may be in a solid state, still believe it to be intensely

(N. C. 98 – Sen

[a] 1° Fah. for every 50 feet.

hot, but suppose that the enormous weight of the outer portions keeps the inner part from melting. They also believe that there are great volumes of melted matter inside the earth from which volcanoes are fed, but that these volumes are small compared with that of the whole earth.

Figure of the earth. Many ages ago Ptolemy proved the earth to be round by the fact that the sun, moon and stars do not rise and set at the same moment to all the inhabitants of the earth. Again, an observer travelling towards the south sees the stars in the north approach the horizon, while new stars come into view above the southern horizon. Other proofs of the earth's sphericity are familiar to every one. Actual measurement, however, shows that the earth is not a perfect sphere, but that it is slightly flattened at the poles, making the polar diameter to be 26 miles shorter than the equatorial.[a] Then, owing to the increasing density of the earth towards the centre, and the great irregularities in the density of its exterior portions, there are many small deviations from its general shape which are often very evident and very troublesome to those employed in geodetic operations.

Size of the Earth. It was by means of the change of position in a star as seen from two different

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[a] The centrifugal force generated by the rotation of a planet when in a plastic state, causes the enlargement of the equatorial parts. This result is strikingly exhibited in the case of Jupiter, as already seen.

points on the earth's surface, that the size of the earth was first ascertained. Thus, supposing the distance between the points to be 830 miles, and that the star is 12° farther from the zenith at one point than at the other (shown by the Zenith Sector), then 1° measures 1/12 of 830 or 69 miles. The whole circumference is then easily found, and from this the diameter, whose proportion to the circumference is known to be the same in all circles. Further, a degree of a great circle in Lapland was found to equal 69 3/4 miles, and thus the flattening at the poles, mentioned above, was also ascertained.

Density of the Earth. Several nice experiments have been made in order to determine the density of the earth. One known as the Cavendish experiment[a] found that a ball of lead one foot in

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[a] In this experiment a very light rod with a weight at each (the smaller balls) is suspended horizontally over a turn-table by a fine fibre of silk. The attracting masses consist of a pair of large leaden balls supported on the table crosswise to the balancing rod, which, by their attraction, they make to turn and vibrate with the twisting and untwisting of the silk thread, until it comes to rest in a position different from its original one. The attracting balls are then placed so as to set the rod turning in an opposite direction from the first, and from the several motions which they give to it in the two positions, their attractions can be computed.

diameter, attracted a much smaller ball 1/20,000,000 part of the weight of the latter, or of the attraction of the earth upon it. The diameter of the earth, roughly speaking, is forty millions of feet. Hence as spheres attract in the ratio of their diameters, if the densities are equal, the density of the earth was learned to be about 1/2 that of lead, or 5.66 times that of water.

Mass[a] or Weight of the Earth. The size or volume of the earth being known, and its density, it is easy to calculate its weight. Thus a cubic foot of water weighs 62 1/2 pounds, which multiplied by 5.66 gives 354 lbs. 6 oz., and this multiplied by the number of cubic feet in the earth gives more than a billion times 6 billion tons for the weight of the earth. The mass of the earth has also been found by its disturbing action on the planets Venus and Mars.

Rotation of the Earth. A body dropped from a great height falls a little to the eastward of a

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[a] Mass and weight mean the same thing, gravity being the same: thus the same mass, as a pound of iron, weighs a pound everywhere on the earth's surface, allowing for the effect which ~~the centrifugal force at the equator, and~~ a decrease of the earth's radius towards the poles have upon it. But the same mass carried to Mars would weigh only two fifths of a pound. The slight difference in the weight of the same mass at high and low latitudes is learned by means of a spring balance.

vertical line because its easterly motion, which it retains during its descent, is faster than that at a lower point. This is one proof of the earth's rotation.[a] The interval between two successive returns of the same star to the meridian of a spectator gives the

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[a] A second proof is more intricate. As the earth rotates, the rotation of its meridians makes the line of North and South at any given ~~place~~ situation describe a circle in the surrounding space. At the equator this line is parallel with the axis, and the direction which it takes in space is therefore not changed by the rotation of the earth. Beyond the equator, the line of North and South makes an angle with the axis, the angle increasing with the latitude, and hence the line of North and South continually shifts its direction as it is carried around by the rotation of the earth. Now if a pendulum is set vibrating in the direction of north and south at any time in the 24 hours, and at a position beyond the equator, it will begin to vibrate out of this direction and continue to do so more and more as the hours pass. This is a proof that the earth rotates from the fact that a vibrating body does not change its plane of vibration because of its rotation, and that it is therefore the North and South line which is really undergoing deflection. And this deflection can only be explained by supposing the earth to turn on its axis once in 24 hours.

The change of direction which the north and south line undergoes in our sky is shown by the apparent revolution of the northern circumpolar stars past the north~~ern~~ point of the horizon. The fixity of direction which the same line maintains at the equator is evident from the fact that here the poles themselves mark the north~~ern~~ and south points of the horizon.

time of the earth's rotation. This is found to be 23 h. 56 m 4 s.09. The ordinary day is about 4 minutes longer, on the average, because of the earth's revolution around the sun.

The Annual Revolution of the Earth. This revolution, as already mentioned, is performed in an ellipse, and hence the earth's distance from the sun varies during the year. When nearest the sun, the earth is said to be in perihelion; and when farthest from it, in aphelion. The nearer a body is to the sun the faster it moves in its orbit, and hence the earth moves faster in perihelion than in aphelion, while the perihelion point must also lie within a shorter half of the orbit than the aphelion. It therefore follows, the earth passing its perihelion in Dec., that the interval from fall to spring is a few days shorter than the opposite interval.[a]

The axis of the earth is inclined to the plane of its orbit at an angle of 66½°. This is known from the fact that the sun's least polar distance is 66½° as observed at noonday of the summer solstice. It follows from this inclination that the planes of the equator and the ecliptic are inclined to each other at an angle of 23½°, the ecliptic or apparent path described by the sun during the year obviously lying in the plane as the earth's orbit.

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[a] "Owing to the eccentric position of the sun within the earth's orbit, it is 184 days from the vernal to the autumnal equinox, and 181 days from the autumnal to the vernal equinox." Young.

It is a remarkable mechanical fact that nothing is so permanent in nature as the axis of a body in rapid rotation, as a spinning-top for example. Hence the axis of the earth retains its fixed direction notwithstanding the constant change of direction which the earth makes in its revolution. But, as explained elsewhere (See "Precession of the Equinoxes" p.) there are causes which result in an excessively slow change of direction in the earth's axis.

The revolution of the earth about the sun is proved by the aberration of light and by stellar parallax. (See "The Stars" p.)

The earth's velocity in its orbit is ~~18.24~~ about 19 miles a second, in moving which distance the earth deviates from perfect straightness by less than 1/8 of an inch. Prof. Newcomb says that our earth has probably been revolving in its orbit for ten millions of years.

Day and Night. These two periods succeed each other very differently, as to length, in high and low latitudes, owing to the great difference of rate at which the sunlight, moving north or south, crosses a large or a small parallel of the earth's surface. At the equator day and night are always 12 hours long, because the circle of illumination at all times necessarily divides the equator into two equal arcs. Beyond the equator, the proportion of each parallel which is in sunlight is less than half from fall to spring, and more than half from spring to fall,

the difference increasing with the latitude. It also increases as the sun moves away from the equator in crossing the torrid zone. Further, the difference in the proportion of the day and the night arcs on successive parallels increases at such a rate, with the advance of summer or winter, that one of the periods ceases altogether at the polar circles at the times of the solstices, and the entire frigid zones are one in day and the other in night, according to the season. At the times of the equinoxes, when the sun is vertical at the equator and shines from pole to pole, it illuminates one half of all the parallels, and thence day and night are each of 12 hours length all over the earth's surface at these times. The sun also now rises and sets everywhere in the east and the west[a]. But when it is vertical north or south of the equator, it rises and sets north or south of the east and west points as many degrees of the horizon as are included between these points and the parallel illuminated vertically.

Constant day and night alternate with each other every 6 months at the poles, while between the poles and the polar circles, periods of alternate day and night such as we have, occur between the periods of constant day and night. The latter periods shorten and the former lengthen with removal from the pole.

Every place on the earth's surface has 6 months of day

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[a] The poles excepted, for here there is but one cardinal point, the north or the south.

during the year, and 6 months of night[a], but the amount of solar heat received at any place depends greatly upon the altitude of the sun above the horizon. This altitude averages about the same within the tropics, but beyond these circles the sun's range in the sky is lower and lower with increase of latitude.[b]

The Seasons. There is no sharp transition from one season to the next, but, astronomically, the seasons are said to begin at the times of the equinoxes and the solstices, or about the 20th of the months of Mar., June, Sept., and Dec. For about two months at midwinter and midsummer there is very little change in the relative lengths of the day and the night, and hence the continued loss and gain of heat during these respective periods culminates in our coldest and hottest weather some time in Jan. and July. There are local and atmospheric conditions which also determine the character of a season. The tropics experience only two seasons, the wet and the dry, and this is the case with the western seaboard of the United States.

a This, though nearly true, is not accurately so. Refraction by causing the sun to be seen above the horizon for an interval when he is ~~just~~ below, adds to the day, and so does twilight. The difference between the two intervals mentioned in a p. 25 also lengthens the day of the north frigid zone over that of the south.

b A globe with day circle will illustrate very clearly the variety of day and night over the earth's surface during the year.

The Moon.

Owing to the comparative nearness of the moon to us,[a] it has been more fully examined than any other celestial object, but not with the distinctness which many imagine. Thus Prof. Newcomb says it is doubtful whether the moon has ever been seen with any telescope as well as it ~~could be seen~~ with the naked eye at a distance of 500 miles. This is because the light of an object is diminished with an increase of telescopic power, and also because the undulations of the atmosphere, which are a great annoyance to the telescopist, are multiplied precisely in proportion to the power employed. The Distance of the Moon. This has been obtained in several ways. The following is a very ancient and simple one: The moon passes through the earth's shadow, or describes the breadth of the earth, in eclipse, in about 4 hours; then in one day she describes 6 times the breadth, and in 30 days (nearly), the time of her monthly revolution, 180 times the breadth, or 180 times 8000 miles, which is obviously the circumference of her orbit. The radius of her orbit, or her distance, must therefore be 1/6 of 1,440,000 or 240,000 miles.

The moon's parallax[a], and thence her

[a] The difference between the directions of a body as seen from two different points is termed parallax. It is by means of their parallax that the distances of the

distance, has been obtained as follows: If at the same instant of time the moon is seen 108° from the north pole, at Greenwich, and 73½° from the south pole, at the Cape of Good Hope, then 108° + 73½° − 180°, the distance of pole from pole, gives 1½° for the parallax of the moon; the diameter of the earth being the base line.
On if the moon is 2° below a certain star, at

heavenly bodies are generally determined.

The parallax of the same body obviously varies with the distance between the observers, which distance, called the base-line, is one of the factors of the problem. The equatorial radius of the earth is the standard base-line among astronomers. Any base-line, seen from a celestial object, subtends an angle of the same amount as the parallax obtained by means of the base-line. Thus the apparent diameter of the earth seen from the moon at her mean distance, is known to be 1°54′5″.4 from the fact that the moon's mean equatorial horizontal parallax (so called whenever the equatorial radius is the base-line) has been found to be one half of this amount.

The only base-line that shows any parallax or displacement in the case of the stars (See p. 155), so immense is their distance, is the diameter of the earth's orbit. The greatest parallax that can be detected in the sun is also small, being about 1/218 of its apparent diameter. This parallax (nearly 9″) is about 9 times that of the nearest star.

The most accurate and convenient instrument for measuring parallax is the meridian circle, which requires the observations to be made at two stations remote in latitude. (See p. 155 for further explanation of parallax).

Greenwich, and ½° below the same star, at the Cape of Good Hope, 2°-½° gives the same parallax:

Or, at a single observatory, the moon's distance when nearest to the north pole, added to its distance when farthest from the north pole, exceeds 180° by an amount known to be due to parallax, as in the former cases.

The parallax of the moon being the same as the apparent radius of the earth seen from the moon, as already mentioned, it is easy to compute how far from the moon the earth must be situated for its radius to equal this parallax, or 57′2.7″ of arc.

The Size of the Moon. The distance of the moon being known, its size may be learned thus: As the distance at which an artificial disk must be held to cover exactly the moon's disk, is to the diameter of the artificial disk, so is the distance of the moon to her diameter:

Or thus: As the apparent radius of the earth, seen from the moon (necessarily equal to the moon's equatorial horizontal parallax) is to the apparent diameter of the moon, so is the earth's radius to the moon's diameter, which has thus been found to be 2,159.6 miles.

The variation of the moon's apparent size, owing to her varying distance, is considerable, this size comparing as the numbers 4 and 3 when she is nearest to us, and when she is farthest from us. This variation of distance follows from the eccentric situation of the earth within the moon's orbit, due to its ellipticity.

The Mass of the Moon. The moon's mass bears the same

proportion to the earth's, that the distances of the two bodies from their common centre of gravity (See p.) bear to each other. This proportion is as 1 to 81 nearly; the moon's volume is about 1/50 of the earth's, showing her density to be 5/8 of the earth's, ~~It is, in fact~~ or rather less than $3\frac{1}{2}$ times the density of water.

The proportion of the moon's mass to the sun's has been learned from the proportion of lunar and solar precession, and also from the proportion of lunar and solar tides.

The Motions of the Moon. The moon has the two motions, axial and orbital [a], which are common to the

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[a] There are over 60 interruptions to the general course of the moon in her orbit. These are dues chiefly to the change of distance and direction from the sun which the moon and earth are constantly undergoing during their orbital journeys, and the consequent change of the gravitating action of the three bodies upon each other. Airy says of this subject that it is involved in mathematical perplexity beyond anything else that he knows. The largest of the lunar inequalities are called the Evection, the Variation, and the Annual Equation. All three cause the moon to be alternately in advance and in arrear of her elliptic place during certain definite periods. The motion of the moon is also sensibly disturbed by the planet Venus. This disturbance puzzled all astronomers for 50 years, but has lately been explained by Prof. Hansen, of Gotha.

motions, axial and orbital,[a] which are common to the bodies of the solar system, but it is remarkable in the moon's case, that she makes one revolution on her axis in the same time that she goes once around the earth, from which it follows that she always presents the same hemisphere to the earth.

bodies of the solar system, but it is remarkable in the moon's case that she makes one revolution on her axis in the same time that she goes once around the earth, from which it follows that she always presents the same hemisphere to the earth. Whether the lunar day was always of the present length is not known[a], but that it should so exactly correspond with the lunar month is attributed to a slight elongation of the moon in the direction of the earth. The excess of material directed towards the earth is not sufficient, however, to follow the earth's pull upon it at once, and hence we do not see exactly the same face of the moon at all times, but more or less around the western or the eastern side, according as the moon, at her varying distances from the earth, moves at a faster or a slower rate in her

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[a] Newcomb says: "If the moon were once in a partially fluid state, and rotated on her axis in a period different from her present one, then the enormous tides produced by the attraction of the earth, combined with the centrifugal force, would be accompanied by a friction which would gradually retard the rate of rotation until it was reduced to the point of exact coincidence with the rate of revolution round the earth, as we now find it. We therefore see in the present state of things a certain amount of probable evidence that the moon was once in a state of partial fluidity."

orbit than the average. This apparent swaying is called the libration in longitude.[a]

The Moon's Annual Motion. We generally overlook the moon's annual revolution around the sun in considering her shorter one around the earth. But, in fact, the earth and the moon travel jointly around the sun in such a way as to appear to move around each other every month[a, p. 35], as illustrated in the accompanying figure (p. 35). In this figure the earth and the moon are supposed to be situated at the top and bottom of the short crosses drawn about the circumference, and to be revolving about the point, representing their common centre of gravity, in which the crucial lines intersect each other, a point actually about 1000 miles

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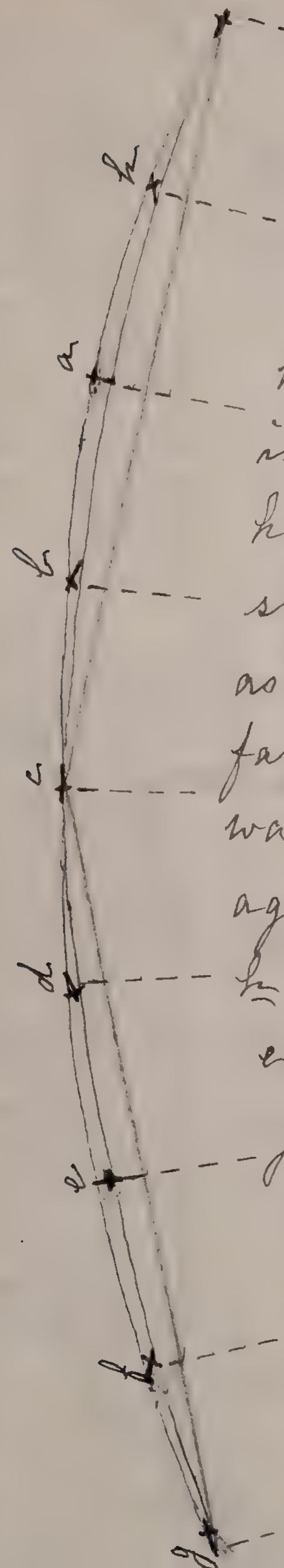
[a] A libration in latitude follows from the fact that the moon's axis is not quite perpendicular to the plane of her orbit, but makes an angle of 83½° with it. In consequence the lunar poles incline alternately 6½° to and from the earth, just as the poles of the earth incline alternately to and from the sun. Further, a diurnal libration arises from our viewing the rising and the setting moon from positions on the earth's surface which are considerably (4000 miles wherever the moon culminates in the zenith, see "The Moon in the Horizon, p. 45") to the right and to the left of the position from which we see the moon when on the meridian. These 3 librations enable us to see nearly 6/10 of the whole surface of the moon.



below the earth's surface. The sun's place in the figure is in the direction of the dotted lines, which lines would meet if prolonged far enough. At cross a the moon end is towards the sun, and the moon therefore shown to be new. At cross b the moon is shown to be crescent, at c, in quadrature or half-full, at d, gibbous, and at e is is again shown in a line with the earth and sun, as at a, but now full. At f, g, and a point farther on corresponding to h, it returns backward through its intermediate phases to new again. By comparing the crosses b, c, d, f, g, and h with each other, it will be seen that the earth is sometimes ahead of the moon in its journey around the sun, ~~as~~ at b, c, and d, and sometimes behind it, as at f, g, and h.

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a" (belonging to p. 34) Strictly speaking, the moon does not revolve around the earth any more than the earth around the moon; but, by the principle of action and reaction, both move around their common centre of gravity. The earth being 80 times as heavy as the moon this centre is situated within the former, about three-fourths of the way from its centre to its surface."

Newcomb.

The distance of the gravitating point from the earth's centre is obviously 1/81 of the distance between the earth and the moon.

In the former case the sun will be seen ahead of its mean place, or its place as seen from the common centre of gravity, which moves uniformly forward, and in the latter case, or with the earth at f, g, and h, the sun will be seen behind its mean place in the ecliptic. This monthly oscillation in the longitude of the sun affords one of the means of estimating his distance from us.

It will also be seen in the figure that the orbits of the earth and the moon are everywhere concave to the sun's place (the two chords drawn from the centre to the ends show this geometrically) and that they alternately open and close in forming the outer and inner portions of the combined figure which the two bodies describe around the sun. Now although the moon is thus connected with the earth by gravity, so that the two bodies forever circulate about one common point, though, from the superior mass of the earth this point lies below the terrestrial surface, the sun really attracts the moon with more than twice the power that the earth does. But because he also attracts the earth with almost the same degree of force, the two bodies remain in company instead of the earth's being left moonless by the dropping of her associate towards the sun.

Since, as shown in the figure, the earth and moon travel similarly around the sun, there are certain phenomena resulting from their relative situation to each other and to the sun, which must be common to both bodies.

1st. The difference between the earth's rotation (360° in 24 hours) and the rate of the moon's motion in her orbit around the earth during the same time (13°1/2) gives the rate of the moon's motion across the sky from east to west:

Hence, the difference between the moon's rate of rotation (360° in 27d. 7h) and the rate of the earth's motion in her orbit around the moon (360° in 27d 7h) gives the rate of the earth's motion across the lunar sky from east to west. Owing, however, to the libration in longitude and the diurnal libration, already mentioned, the earth sways eastward and westward a few degrees during the lunar day.

2dly. The inclination of the moon's orbit to the earth's equator gives the farthest northern and southern range of the moon in our sky. (See p.)

Hence, the inclination of the earth's orbit (ecliptic) to the moon's equator, ~~which is~~ (1 1/2°) gives the farthest northern and southern range of the earth in the lunar sky, and also the amount at which the lunar poles tip to and from the earth.

3dly. The inclination of the earth's axis to the plane of her orbit gives the farthest northern and southern range of the sun in our sky, and determines the width of the torrid and frigid zones:

Hence, the inclination of the moon's axis to the plane of her orbit (6 1/2°) gives the farthest northern and southern range of the sun in the lunar sky and determines the width of the torrid and frigid zones of the lunar surface.

Note. The last statement needs qualification, the moon in more respects than one being a very peculiar member of the solar system. The smallness

of the convex globe is such that, at an elevation of 900 feet, the eye penetrates 1°30' below the true horizon. Now there are at the north pole mountains 9500 feet, and at the south pole 3,000 feet high: consequently the summits of these mountains can never be hidden from the sunlight. (Beer and Maedler) For the same reason the earth is always visible from pole to pole at the moon's surface.

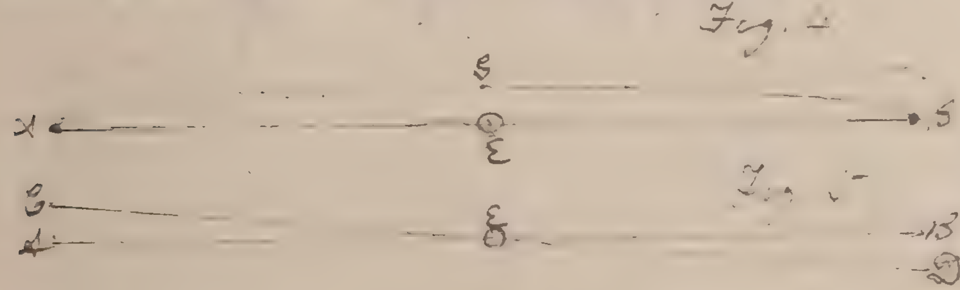

Fig. 4 shows the proportion of the earth's diameter E to the radius EK of the moon's orbit, and also to the inclination ES of the lunar orbit to the ecliptic, as seen from the direction of the sun. Fig. shows the lunar orbit opened out to its widest extent, and the moon at S and therefore new or full, at its greatest distance above or below the earth. In this figure the distance ES is greatly foreshortened, owing to the direction in which the radius ES is seen. ~~which are~~ situated at a much greater distance from the eye. In fig. the two orbits are seen as from above, from which it follows that the radii of the lunar orbit (the crosses) appear everywhere of the same length as they are in reality, allowing for the ellipticity of the orbit. Fig. shows the orbit seen edge-wise and the moon therefore at new or full, in the same line of sight as the earth at E, as happens at eclipses. Conceiving the diameter E to be 3 2/3 times that of the dots A or B, we have the proportion of the lunar to the terrestrial diameter.

Phases of the Moon. The moon is an opaque body, having one half of its surface always illuminated by the sun. When the illuminated half is wholly turned from the earth, in which case the moon is not seen, she is said to be new.[a] When the moon's motion in her orbit has brought half of her bright face into view, she is in her first quarter. When the whole of her bright face is towards the earth she is full, and when half of her bright face has been carried out of view she is in her third quarter. At intermediate positions she is crescent between "new" and her "quarters", and gibbous between "full" and her "quarters."[b]

Moonlight. According to Sir John Herschel, the moon's light is not much superior to that of weathered sandstone rock in full sunshine. According to another statement (Zöllner's) it would require 619,000 full moons to make bright daylight. When the moon is nearly new, the dark portion of its face is seen faintly, an appearance called the "ashy light", or, in

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[a] The new moon is lost to view about four days.

[b] The moon's phases may be illustrated by laying a conspicuous strip around the middle of a ball, and then revolving the ball in a direction contrary to that of the strip.

popular phrase the "old moon in the new moon's arms."[a] This arises from the shining of the earth, which is nearly full to the moon at this time, upon the moon's surface, which reflects back again a portion of the strong earth-light with which it is illuminated. As the moon gains age in her revolution, more and more of the night side of the earth is turned towards the moon's face, whose dark portion in turn gradually becomes invisible.[b]

High and Low Moon. As the moon always fulls opposite the sun's place in the ecliptic, as regards longitude, it follows that when the sun runs low, as in winter, the full moon describes its longest and highest arcs, while in summer it in turn runs low.

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[a] The exterior outline of the new moon is now seen to project sensibly beyond that of the old moon, an appearance caused by irradiation, objects having an apparent dimension considerably greater when they are illuminated by a more brilliant light.

[b] An observer on the moon would see the earth go through the phases the moon presents to us, but instead of rising and setting, it would only oscillate back and forth through a few degrees. The apparent diameter of the earth would nearly quadruple the moon's, but this striking object would only be visible from about 6/10 of the moon's surface.

In the spring and fall, when the sun is on or near the equator, the moon fulls likewise on or near the equator, describing a half-circle above the horizon. When the full moon runs high, the new moon must obviously run low, and the quarters, intermediate, and thus the ~~different~~ same lunar phase is seen to describe arcs of different lengths at different times of the year.[a]

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[a] The moon's orbit crosses the ecliptic in two opposite points called the moon's nodes. But owing to the disturbing action of the sun upon the moon, when the latter is not in the plane of the ecliptic, these nodes are continually retreating or going towards the west upon the ecliptic, making a revolution of it in about 19 years. It follows from this that the inclination of the lunar orbit to the equator oscillates rather more than 5° on either side of 23½°, or passes from about 18½° to 28½°, and thence to 18½° again during every revolution of the nodes. This change of inclination causes the highest and the lowest moons to range a distance of 10° in the sky, whereby at one time the former come to the meridian 5° higher than the highest sun of the year, and the latter 5° lower than the lowest sun, and the reverse 9 years later.

If the student will trace two opposite semicircles around a globe, starting from the opposite points which lie 5° above and 5° below the solstitial points, and keeping 5° from the ecliptic on both sides, he will find that both semicircles terminate 5° nearer to or farther from the equator, according as he started 5° above the north solstitial point, and 5° below the south, or the reverse. This will show how the

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The Position of the Lunar Crescent. This is often ignorantly regarded as a weather token, it being a common saying that a new moon is dry if the horns or cusps point upward, or wet if they point downward. But the position of the cusps really depends upon the direction of the sun at the time, the cusps being always 90° distant from the point of the lunar surface illuminated vertically, which point lies in the imaginary line joining the centres of the sun and moon. The cusps, in fact, are the points in which the lunar day-circle and that bounding its visible hemisphere intersect each other. When, therefore, the sun descends steeply below the horizon, as in March[a], the moon, if situated at her greatest distance north of the ecliptic, and very young, may, seen soon after sunset, have the line joining its cusps quite horizontal.

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revolution of the moon's nodes effects a change of inclination between the lunar orbit and the equator, and consequently of the moon's range in the sky.

[a] When the western horizon intersects the ecliptic at the vernal equinox in the course of its diurnal revolution around it, the inclination of the former to the latter in northern middle latitudes, is about 62°, but when the point of intersection is the autumnal equinox, the inclination is only about 15°. Consequently, the course of the setting sun about the time of the vernal equinox is much steeper than at the time of the autumnal equinox. This is readily seen by adjusting the artificial horizon of a globe as mentioned.

On the contrary, a very young moon seen at the same hour in Sept., and situated at her greatest distance south of the ecliptic, may have the same line nearly upright to the horizon.

The heat which reaches us from the full moon has been measured and found only equal to 1/3 of that of an ordinary candle placed at a distance of 15 feet; and hence this phase can have but the feeblest, if any power in dissipating clouds, as some assert.[a]

Since, as we have seen, the illuminated portion of the moon's disk rounds towards the sun at all times, it is necessarily turned towards the west from new to full, and towards the east from full to new. In the former case we see the sun rising, and in the latter case the sun setting on the lunar surface.

[a] "The Greenwich Observatory, which is especially engaged with observations upon the moon, has recently fully demonstrated, in its observation register of the moon and weather extending over many years, the complete insignificance of the positions and phases of the moon as affecting the condition of the atmosphere; that all so-called experiences to the contrary must be regarded as possessing not the slightest value." Proctor.

<u>The Harvest Moon</u>. This name has been given to the full moon which occurs about the time of the autumnal equinox, and which rises soon after sunset for several consecutive nights. This near coincidence in the times of rising is owing to the small angle at which the eastern quarter of the horizon crosses the moon's about Sept. 20, whereby the moon's orbital advance of 12° in 24 hours removes her but a small distance from her subsequent place of rising.[a] As the

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[a] If the horizon of a globe be set at an angle of 45° or about with the equator, with its eastern point over the vernal equinox in the ecliptic (the ecliptic serving for the lunar orbit), the small angle which the eastern side of the horizon makes with the ecliptic will show the angle in question. Now counting 12° from the eastern point of the horizon, eastward on the ecliptic, it will be seen that the distance from the point reached, backwards due west to the horizon, is a small one. This is the distance to be passed over by the horizon (for it is the horizon, rotating with the earth, that comes to the moon, and not the moon to the horizon) before the moon appears in it the evening following its rising in the vernal equinox. The difference in value between the angle formed by the horizon and the lunar orbit at the place of the vernal equinox, and the greatest angle formed between the two circles may be seen by setting the horizon, still at 45° with the equator, with its eastern point over the autumnal equinox. Now

moon describes her orbit every month, there is obviously a period in every month when she rises as at harvest-time, but only at this time does she rise full at sunset, from the fact that only at the equinoxes are both the sun and the moon 12 hours above the horizon. The full moon of Mar. and Apr. sets for several mornings about sunrise, and is the harvest moon of the southern hemisphere.

The full moon following Sept. rises for several nights about as near to the time of sunset as the moon of the preceding month, and is sometimes called the <u>hunter's</u> moon.

As the latitude decreases, the phenomena of the harvest moon and the hunter's moon are less marked because of the enlarging of the angle to which they are due. At the equator the moon both rises and sets about 50 minutes later every night, and, like the sun, always

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counting 12° as before, the distance backwards due west to the horizon is seen to be much greater than in the former case. Whenever the eastern horizon makes a small angle with the lunar orbit, the western horizon when brought to the same part of the orbit, will be found to make a large angle, and <u>vice versa</u>. (Owing to the fact that the eastern and western sides of the horizon cross the heavens in opposite directions). Hence, whenever the moon rises about the same time for several consecutive nights, she sets at times varying considerably, and <u>vice versa</u>.

remains 12 hours above the horizon. As the latitude increases, the phenomena ~~of the harvest~~ and hunter's moons are more marked because of the diminishing of the angle to which they are due. Near the Arctic Circle this angle vanishes, and the moon rises about the same moment for a fortnight,[b] but sets at hours varying greatly. This is because the horizon comes nearly into coincidence with the lunar orbit every 24 hours, when, if the moon is on the east, she rises as stated, or if she is on the west she sets about the same moment for a fortnight, but rises at hours varying greatly. At the poles the moon is above the horizon for a fortnight, going around the sky every 24 hours, and she is then absent for a fortnight.

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[a] The inclination of the moon's orbit to the ecliptic, and the moon's variable motion, due to the eccentricity of her orbit, cause the interval at which the harvest moon rises on successive nights to vary from 9 or 10 minutes to more than half an hour. The greatest interval between the hours of full moonrise occurs in spring, and varies from about $1^h 10^m$ to $1^h 30^m$.

[b] In a point of the horizon 12° farther north or south every night according to the direction of the moon's course. When farthest south it would set as soon as risen, but the reverse would be the case with it farthest to the north.

Between the poles and polar circles there are two intervals every month when she is similarly present and absent, but for shorter and shorter periods, until about lati- 66½°, she rises and sets everyday throughout the lunar month. Her course everywhere during a lunation is, in fact, similar to the sun's course during the year.

<u>The Moon in the Horizon</u>. The moon, and also the sun, appear larger when near the horizon than when high up in the sky. Any celestial object, however, is 4000 miles farther off when rising or setting than when in the zenith (where it is seen as from the centre of the earth) for the reason that the spectator is half the diameter of the earth farther off in the former case than in the latter. The moon's diameter has also been found smaller in the horizon than in the zenith by actual measurement; and its apparent enlargement has therefore been ascribed to an illusion of the judgment. The intervening objects of the landscape lie in close comparison with it low down, while its insulation aloft leads the eye to undervalue its apparent magnitude.[a]

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[a] If, when the disk of the moon appears with these illusory dimensions, it is looked at with the naked eye through a tube, or the hands placed tubewise, the illusion disappears; it does not seem then to exceed in size the lunar disk seen at the zenith. Guillemin.

But there is a real change effected in the appearance of the sun and moon when approaching the horizon, by the increasing density of the atmosphere, which causes the disks to assume an oval shape. Very near to the horizon this flattening of the vertical diameter becomes greater on the lower side, producing a singular effect. This action of the atmosphere is called refraction. Refraction raises all the heavenly bodies higher above the horizon in appearance than they are in reality, and even brings those actually below the horizon into sight. Thus we see the sun and moon resting on the horizon, (where this is clear, as on a prairie or the seashore) when their entire disks are below it.[a]

Another effect of the atmosphere is to scatter the solar light in all directions, whereby we have twilight, and, what is far more important, are enabled to see objects which do not lie in direct sunshine.[b] Twilight continues

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[a] A very simple experiment will show the effect of refraction. Place a cent in an empty basin and remove just far enough away to lose sight of it, when, if water is poured into the basin, the cent will come into view by seeming to rise.

[b] Without an atmosphere every place and object not directly illuminated would be black, and over all would be a black sky in which the stars would shine by day as well as by night.

while the sun is from 15° to 20° below the horizon, according to the condition of the atmosphere.

<u>The Surface of the Moon</u>. [a] Light and dark regions are seen on the disk of the full moon, the former of which indicate the mountainous portions, and cover almost all the southern half of the visible hemisphere. The dark regions occupy the northern half chiefly, and are covered with a smaller and darker class of inequalities.[a] One of these, a circular plain[b] walled in by high mountain ridges, is 160 miles in diameter and includes the 760th part of the whole area of the moon. The height of many of the lunar peaks (as measured from the length of their shadows) is prodigious for the moon's size[c]: thus Mounts Dorfel and Leibnitz reach upward 25,000 feet, which, compared to the moon's

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[a] "As the moon is now seen and mapped, the difference between the light and dark portions is due merely to a difference in the color of the material, much of which seems to be darker than the average of terrestrial objects." Newcomb.

[b] These regions were long considered level and have hence received the name of plains.

[c] It would require about 50 moons to equal the earth in size, and 75 to equal it in mass.

radius, is more than 3 times as high as the famous Gaurisankar of the Himalayas.[b]

The lunar mountains are mostly annular, with a flat interior diversified by conical elevations rising here and there. Sometimes a single one occupies the centre of the enclosed plain, as in the great crater Tycho 54 miles in diameter, where the solitary peak is nearly a mile in height. At the centre of another

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[a] Galileo was the first to examine the moon's surface with a telescope. Hundreds of years before, Plutarch, who had seen the shadow of Mount Athos lying 87 miles away, in the market-place of Myrina in Lemnos, thought the irregularities of the lunar terminator indicated vast shadows cast by the lunar mountains.

The <u>lunar terminator</u> is the lunar day-circle, half of which we see as a straight line when the moon is in her quarters.

[b] Strictly speaking, it is out of our power to compare lunar and terrestrial heights, for the reason that we measure the latter from the sea level, while having no such common surface on the moon, the former are counted from the surface of the surrounding plains.

annular mountain, situated at the extremity of the long range called the Apennines, another solitary rock rises 3 miles above the surrounding level. These ring mountains, with their shining summits and black shadows, form very beautiful objects when viewed through a telescope.[a]

Bright streaks radiate from certain of the craters, from Tycho especially, forming a very curious appearance. These streaks pass alike over mountain and valley, and even through the rings and cavities of craters, some of which, issuing from Tycho, have been traced more than 1000 miles. It is supposed that these indicate fissures formed in some past period, and afterwards filled with an erupted, white material which is exposed to view the entire length of the streaks from the absence of any vegetable covering on the moon's surface.

In the lunar valleys are furrows extending in a straight direction for long distances (Schmidt gives them 18 to 92 miles long, 1/2 to 2 4/10 miles broad), and changing in direction (if at all) suddenly, again to pursue a rectilinear course. They pass through levels, intersect craters, and, tunnel-like, reappear beyond obstructing mountains; artificial, however, they cannot be, but are more probably cracks formed by the shrinking of the moon's surface.

"It is very curious that the figures of these irregularities in the lunar surface can be closely imitated by throwing bubbles upon the surface of some smooth plastic mass, as mud or mortar. They may be well seen during an eclipse of the sun, when the contrast between the smoothness of the sun's limb and the roughness of that of the moon cannot escape notice. Their appearance is most striking when the eclipse is annular or total. In the latter case, as the last streak of sunlight is disappearing it is broken up into a number of points which have been known as 'Baily's beads', from the observer who first described them, and which are caused by the sun shining through the depressions between the lunar mountains."

[illegible]

This surface seems indeed to have been shaped by much more violent activities than the surface of the earth. This may possibly be explained by the moon's smaller volume, which would cool off much more rapidly than the earth's; the effects due to subterranean action may also have been greatly modified by her small gravity, which is only 1/6 the amount of terrestrial gravity. Again, these effects may have been modified by the absence, or, at least, the extreme rarity of the lunar atmosphere[a] as compared with the heavy envelope which rests upon the earth's surface. The

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[a] The absence of a lunar atmosphere of any appreciable density is made certain by a variety of phenomena, such as the absence of half-lights (twilight) at the lunar terminator, the sudden extinction of stars at the moon's limb in occultation, of the sun in solar eclipses &c. A lunar atmosphere would reveal the sun to our view as a ring of blazing lustre around the lunar limb.

Guillemin asks if the moon is of gaseous origin, why had it not the power of preserving its atmosphere? In answer, he suggests that the high temperature

absence of air on the moon's surface implies the absence of water, which would at once evaporate from the lack of atmospheric pressure. Especially, the energy of the solar rays could not fail to convert any bodies of water into thick clouds of vapor, but no moving spot, indicative of a cloud, has ever been observed on the moon's disk.

Most truly, as Humboldt has expressed it, is our satellite "a hushed and silent desert", while, to add to its strange conditions, is a temperature probably ranging from 200° or 300° below zero to as much above, between midnight and noonday in its equatorial regions.

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to which each one of the lunar hemispheres is periodically exposed, considerably increased the oxidising power of the lunar substances, whereby these absorbed the gases of any atmosphere which may have existed. Or perhaps the slight weight of these gases enabled the atmosphere to spread itself into a state of extreme rarity, or even to become dissipated in space. Laplace admits the last hypothesis as very probable.

Chapter The Stars

<u>The Number and Magnitude of the Stars.</u>
The whole number of stars visible to the naked eye in the celestial sphere is about 5000. The number shown in the great telescopes of our times probably lies somewhere between 20,000,000 and 50,000,000.

The stars were long ago arranged into 6 magnitudes, according to their apparent brightness. These magnitudes number, nominally, from the north pole to the circle 35° south of the equator, ~~about~~ as follows:[a]

Of magnitude 1, there are about	14	stars
" 2 "	48	"
" 3 "	152	"
" 4 "	313	"
" 5 "	854	"
" 6 "	2010	"
Total visible to naked eye	3391	"

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[a] This table is taken from Newcomb's Popular Astronomy.

This limit includes all the stars visible throughout the year in the Middle States, excepting a few southern ones.

The telescope continues to reveal a decrease of magnitude according to the optical power employed, but no exact scale has been arranged for rating stars below the 16th magnitude.

Stars of the same magnitude often differ perceptibly in brightness, the fact being that the 6 or 16 magnitudes of the astronomical scale embrace an infinite number of magnitudes which grade insensibly into each other. Attempts have been made to substitute a more exact comparison than that of magnitudes by measuring the light of the stars, both in color and intensity, with that of an artificial star whose light can be varied at pleasure. Among the results thus obtained is the interesting one that Sirius gives us four times as much light as any other star in our sky.

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* The visibility of this magnitude depends greatly upon the power of the eye and the condition of the atmosphere.

N. 45 Stars shine unequally both on account of
their unequal distances from us and on account
of their unequal amount of light which they
radiate, or the difference in their absolute
N. 482 brilliancy. In the latter respect they appear
to range through 8 or 10 magnitudes, the
largest of them emitting several thousand
times as much light as the smallest. It
is this range of absolute brilliancy which
forms the greatest obstacle in the way of
determining the arrangement of the stars
in space. The star the nearest to our
system that is visible in our latitude, is
N. 316 the double star 61 Cygni of the sixth magnitude, while Sirius outshines every other star
N pp 362537 in the heavens at three times the distance.[a]
The difference between these two stars in magnitude
and brilliancy is therefore known to be immense.

N. 459 [a] This distance is more than a million radii of the earth's orbit.
207 α Lyrae, at more than twice the distance of 61 Cygni, is ~~also~~
nearly a hundred times as bright as either of the
components of 61 Cygni.

Division into Constellations.

The unequal scattering of the stars over the
S. 412 sky led to their division into constellations very
many ages ago. The imaginary figures including
the principal stars of each of these, with the accom-
panying names, have been retained to the present
day, but the figures no longer possess their an-
cient importance, whatever this may have been,
S. 413 and are often omitted in the preparation of star maps.

Naming the Stars.

The ancient methods of nomenclature
are still in popular use, as the eye of the
S. 415 Bull, the tail of the Great Bear, Sirius, Arc-
turus, Aldebaran, &c. For astronomers the
following system has been designed: The letters
of the Greek alphabet are given to the conspicu-
ous stars in each constellation, the 1st letter
S. 416 to the brightest, the 2nd to the next brightest,
and so on. If the number of Greek letters is
insufficient, the Latin alphabet is then used,
and, after this, numbers are employed if
there are still unnamed stars in the con-
stellation. Each letter or number is followed

by the Latin names of the constellation in the genitive case; as α Lyrae, 61 Cygni &c.
For a star not catalogued, its declination and right ascension must be given.

<u>The Milky Way</u>. The Milky Way or Galaxy is a zone of white light of varying breadth and intensity, which surrounds the entire celestial sphere at an angle of about 63°
446 to the equator. It follows from this inclination that the zone nearly coincides with our horizon once every 24 hours,[a] from
446 which relative situation its visible arch rises higher and higher the next 12 hours until its highest point[b] lies about half way between the pole and the zenith. This arch,

[a] This happens in the early evening during the spring months; at all other times of the year, its arch can be readily seen.

[b] It is evident that this point describes the same daily circle around the pole that a star in the same latitude (63° N.) describes. The former, like the latter, comes

(See p. 123) 6

like the constellations, occupies the same place in the sky about four minutes earlier every successive 24 hours.

The Milky Way is divided into two prominent though unequal streams for about 150° of its course, the narrower of which is broken by a wide gap in the region of Ophiuchus, while a conspicuous diversity of patch and interval marks the main stream east of this region, in the Eagle. The most noticeable feature of the Milky Way, however, is a dark pear-shaped vacancy in the midst of a bright mass about the Southern Cross, its striking blackness really arising from its contrast with the brilliant region by which it is surrounded. This vacancy was named the Coal-Sack by the early navigators. A broad dark space not

Hers. 446

H. 445

H. 448

H. 447

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to the meridian above the pole star or below it, according as the longitude of either and the observer's coincide or are 180° apart.

(The varying altitudes of the Milky Way can be well illustrated on a globe having a terrestrial and a celestial horizon.)

unlike the Coal-Sack may be seen in the
H. 448 irregular galactic region about the Swan.
H. 447 The continuity of the Milky Way is again interrupted
(7th line from top) by a wide gap in the constellation of the Ship
in the southern hemisphere. The zone is also
varied by occasional offsets, such as proceed
H. 446, 448 bottom southward through Perseus and northward
through Cepheus.

The telescope shows the Milky Way
to consist of an immense assemblage of
stars too minute to be seen separately with
the naked eye. These are distributed with
H. 452 (bottom) remarkable uniformity over some regions,
453 (top) and cluster richly around few intervals
in others. In many parts the zone has been
so completely resolved as to show the stars
Burdem, "The Heavens" projected on a black ground, while the
whitish glimmer still seen behind the
stars in portions of the zone show it to be
really impenetrable in these directions.
Its description of a great circle, nearly,
around the heavens, makes it certain
that the earth is situated within it,

H. 475 but two facts suggest that our planet is not quite central, either to the circuit of the zone or to its thickness. These are; the greater brightness of

H. 447 the southern part of the circuit[2] over the

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[2] "Throughout all this region" (about the Southern Cross, already mentioned) "its brightness is very striking, and when compared with that of its more northern course, conveys strongly the impression of greater propinquity, and would almost lead to a belief that our situation as spectators is separated on all sides by a considerable interval from the dense body of stars composing the Galaxy, which in this view of the subject would come to be considered as a flat ring of immense and irregular breadth and thickness, within which we are excentrically situated, nearer to the southern than to the northern part of its circuit." (Herschel of the Milky Way in Outlines of Astron. p. 447).

"Travellers in the southern hemisphere fully confirm the extraordinary statement made by the late Captain Jacob (a careful astronomer and observer), that 'the general

northern, and the greater density of [a] stars to the
H. 452 south than to the north of the plane of the zone."
The near approach of the divided portion of the zone to a half circle also shows that the earth
H. 446 must lie somewhere near the place of cleavage into the two principal laminae which, as we shall see, form this portion.

H. 447 The inclusion of the earth within the Milky Way makes it very difficult for the astronomer to conceive what shape this encircling cluster would present if seen from without. The study of its structure [b]

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light from this portion of the sky is such as to render a person immediately aware of its having risen above the horizon, though he should not be at the time looking at the heavens, by the increase of general illumination of the atmosphere, resembling the effect of the young moon.'"

<u>The Great Nebula in Argo</u>, by R. A. Proctor.

a "The sun, moreover, is a little out of the plane of the Galaxy, since this zone does not form a great circle, but a parallel to a great circle, and distant from it about 8°." Secchi.

b This subject was first investigated by Sir
H. 465 Wm. Herschel in his unrivalled soundings of the heavens.

Newcomb Pop. Astron. [illegible] 363 p 465, 473 (Pop.)

has left no serious doubt, however, that it consists of a stratum of suns of the figure, generally, of a flattened millstone,[a] the rim of which is split into two portions or laminae throughout nearly one half of its circumference. This stratum most probably includes the whole visible universe.[b]

Clusters. It has been shown that there is a regular and gradual condensation of stars towards the galactic belt. Ne-

(read below a first)

[b] "The majority of the resolvable nebulae lie near the direction of the plane of the Milky Way, which implies that they constitute part of this system, for otherwise the probability against the great mass of them lying in one plane would be very great." Pop. Astron. by S. Newcomb. p. 482

[a] Such a figure would necessarily show a decrease of stellar numbers with removal from the Galaxy, as viewed from the earth.

p. 479 The diameter of the stratum is estimated to be 8 or 10 times its thickness.

"100 million stars are presumed to be disposed in a flat, circular layer of such dimensions that a ray of light would require 30,000 years to traverse our diameter." Rob. S. Ball of Milky Way in Pop. Sci. Mon. May, 1881.

also find stars condensed into clusters in various parts of the heavens. Some of these clusters are visible as separate stars, like the
N. 417 Pleiades, but more commonly they show as milky patches, from the smallness of the component stars. Seen through a telescope, these patches are resolved into hundreds and thous-
N. 441 ands of stars, and sometimes their multitude and minuteness make any count of them an impossibility. The distance of many clusters is beyond all conception, showing the celestial spaces to be infinite to our
N. 443 comprehension, and perhaps so in fact. These clusters appear only as minute patches in the most powerful telescopes, yet each constitutes a firmament seemingly as remote as our own to the beings who may dwell upon its several planets. And just as one individual differs everywhere from another in the domains of nature, so must every firmament have its particular constellations, which, in many cases, probably far excel those of our own sky in picturesqueness
Guil. 314 and splendor. Some common bond of attraction

is supposed to hold together the suns that form a cluster.

A. 417 <u>Nebulae</u>. These are irregular masses of cloudy light which the telescope fails to resolve into stars. The spectroscope has within a few years shown why this is so, by proving

A. 445, that these objects consist of immense quanti-

452 ties of glowing gas. It is the opinion that this

495 gas is the crude material out of which suns and systems are forming.

A. 450 Nebulae are most numerous where the stars are least so, and hence very few are found in the Milky Way. Outside of this region they are chiefly confined, in the

A. 502 northern hemisphere, to a certain district included within and embracing portions of Virgo, Leo, Ursa Major and Boötes.

The <u>Magellanic</u> <u>Clouds</u>, near the

Brit. south pole, are distinguished from all other

357 nebulae by their great apparent dimensions, and by the combination in them of star-clusters

A. 576 and nebulae, which elsewhere are strikingly separate from each other. The larger is 200

2 v.l. 356 times the apparent size of the moon, and the smaller one fourth of this size. Strong
H.515 moonlight totally obliterates the latter, but not quite the former.

A few nebulae are round and well-defined. These are called planetary nebulae.[2]
S.441

H.509 Sometimes a sharp and brilliant star is seen surrounded by a circular atmosphere
H.570 of faint light. In many cases the star is double and the nebulosity more or less elliptical. These are called nebulous stars. Two phe-
H.577 nomena, the zodiacal light and meteoric bodies, seem to indicate that our sun is a-

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[2] "The remarkable class of objects termed Planetary Nebulae, when viewed in the 6-feet reflector of Lord Rosse have failed to exhibit that uniform aspect which had proved such a stumbling block to Herschel in his attempts to explain their structure. 5 nebulae, which previous astronomers had represented as possessing a round uniform disk, were found by Lord Rosse to exhibit unequivocal indications of an annular structure." His. of Phy. Astron. by Rob. Grant. p. 13

14

N. 449 nebulous star. The nebula surrounding the remarkable variable star η Argus is believed with reason to be subject to great changes of form, and changes have been suspected in other

Guil. nebulae. Nebulae also appear in groups, not merely optically, but physically.

<u>Variable Stars</u>. These exhibit changes of brilliancy, generally losing and recovering their light at regular intervals of time. The two most striking examples of these stars, among

N. 426 the hundred or more now known, are Algol in Perseus and Mira in the Whale, in both of which the variation is so decided that the most casual observer has only to look at the proper times in order to see it. Algol ranges

N. 427 from the 2d. to the 4th magnitude and back again during an interval of about 9 hours every 3 days. But while it remains of the

N. 427 4th magnitude about 20 minutes, it is visible as a 2d magnitude star for about 2d. 12 h.*

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*"Near the beginning and end of the variations

N. p. 427 the change is very slow, so that there are not more than 5 or 6 hours during which the ordinary eye would see that the star was any smaller than usual." Newcomb.

Mira is generally invisible to the naked eye, but every 11 months it shines as a star of the 2d or 3d magnitude. It requires about 40 days for it to attain its greatest brightness, and about 2 months to become again invisible. η Argus of the southern hemisphere is remarkable for its great brilliancy at the maximum, and for the range of its magnitude, it being invisible to the naked eye at the faintest. This star requires many years to complete its changes, which recur somewhat irregularly. The star, in fact, ranks midway between the regular and the irregular variables, the latter being also called new stars.[a]

New Stars. In November, 1572, an apparently new star suddenly showed itself in Cassiopeia. It brightened rapidly, soon becoming equal to Venus, began to fade in December, and had disappeared entirely by the following May. In 1604 a star of the 1st magnitude was suddenly seen in Ophiuchus. It remained visible

[a] See p. for the color of variables.

through 1605, fading away entirely in 1606.
In 1866 a star of the 2nd magnitude suddenly
1 433 appeared in Corona Borealis, and faded out of
sight in a few days.[a] All these stars seem to
have blazed up with great rapidity, and with-
1 432 out much doubt still remain as very small
1 433 stars, and existed as such before their sudden
accession of light. The star of 1866 was indeed
recorded as one of the 9th magnitude in Arge-
lander's catalogue completed several years
before. It is not likely that stars are ever cre-
ated or annihilated on a sudden, but that
1 433 all such reported cases are very fitful variables
like those just described, or that errors in cat-
1 432 aloguing stars have led to their supposition.
Astronomers have discovered stars of nearly every
degree of irregularity between the regular vari-
1 433 ables like Algol, and those very irregular stars
which blaze up in a single occasion in the
course of centuries. The variations which proceed
1 434

[a] A new star in the great nebula of Andromeda has been observed the present season. It is now (Sept. 3) of the 6th magnitude and easily visible to the naked eye.

regularity are probably caused by operations similar
... 25 form to those which produce the solar spots,
while it is not unlikely that the occasional out-
burst of a star is due to an extraordinary erup-
tion of hydrogen gas from the star, as the spec-
trum of the star of 1866 seemed to indicate.
... 25 This would show an action similar to that
which produces the solar flames, only on an
immensely larger scale.

Double and Multiple Stars.[x] These are
either optical or physical. In the former case
they chance to lie within a few seconds of each
8.480 other, at very different distances from the eye, and
without any mutual gravitation. In the
latter case, they form a single system, turning
Guillemin round a common centre of gravity and having
a common proper motion. The distance of any of
Loomis the physically connected being known, the
form and dimensions of their orbits and also
their periods can be calculated. It has thus
been found that the components of the stars

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[x] For examples of these stars, also of clusters and nebulae, see the Constellations.

H. 486 forming 61 Cygni are about 45 times as distant
Smith. from each other as the sun is from us.[a]

H. 437 The periods range from a few decades of years to
437 centuries, generally the latter. The orbits are el-
Rolfe, 152 lipses, so far as observed. Many of the double stars
H. 457 exhibit a striking contrast in the colors of their
components.[x]

<u>Proper Motions of the Stars</u>. The stars are
Rolfe 7 known to have a motion of their own called their
<u>proper motion</u>, but, owing to their immense distance
H. 453 the eye alone would detect no consequent change
of place in most of them for thousands of years.
We commonly find the brighter stars to have the

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[a] Knowing the radius of the orbit and the
H. 486 period of the star, we can compare its mass
& Lomm with that of our sun. We thus learn that the sum
[illegible] of the masses of the components of 61 Cygni is about 1/3
[illegible]) of the mass of our sun.

~~[c] Herschel, seeking for the parallax of stars, discovered their revolution, which so occupied his attention that he dropped the problem of parallax.~~
~~H. 234 Bradley also tried for parallax and discovered the aberration of light (See p.) leaving the discovery of stellar parallax to be finally made by Bessel.~~

greatest proper motions, but there are noticeable exceptions to this rule. Thus the telescopic star known as Groombridge 1830, in the Hunting Dogs, moves along the sky at the greatest rate, 61 Cygni of the 6th magnitude at the next greatest, following which are four or five others of the 4th and 5th magnitudes. The rate of the first carries it over 7" of arc[a] annually, which amount, combined with its known distance shows its actual velocity across our sky, to be no less than 200 miles in every second of time.

The short arcs described by the stars
45-3 stars since the first accurate determination of their positions, exhibits no curvature[b], showing their

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[a] "This is 70 times the parallax of the star, showing it to move over a space of more than 70 times the distance of the sun from us, in the space of a year, and if its motion is oblique to the line in which we see it, as is likely, its actual velocity must be yet greater." Pop. Astron. by S. Newcomb.

[b] That is, no curvature except the apparent one of the celestial sphere which forms our sky. If a star were revolving in an orbit level with the eye, it would also exhibit no other curvature, but

orbits to be immense if they move in a definite orbit. But any associated circulation around a common centre seems to be denied by the fact
N. 45-4 that they everywhere move in all directions, with every rate of velocity. Coupled with this variety there is indeed an apparent general movement
N. 45-5 of them all towards the constellation Argus, but this is believed to be due to a real motion of our sun and solar system in the opposite direction.

N. 45-2 The Solar Motion. We know our sun to be a star [see p. 14] 26 and are therefore prepared to find it in motion, as well as the other stars. The direction of this motion, according to a number
N. 45-4, 465 of eminent astronomers, is towards the constellation Hercules, and its amount relative to our system such that if the sun were viewed squarely to the direction of this motion from the distance of an average star of the first magnitude, it would appear to move at the

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following an orbit inclined to the eye, it would trace a curve around some point of the celestial sphere, the form of the curve being more or less elliptical according to the inclination of the orbit.

rate of 33".9 per century (Struve). This is equivalent to about 5 miles a second.[a]

4.494

Motion of Groups of Stars. Several widely
4.455
extended groups of stars have been found moving in a common direction along the sky, showing that they form connected systems. The most remarkable case of this kind
4.456
comprises a large majority of the brighter stars between Aldebaran and the Pleiades, which advance about ten seconds per century towards the east. 5 of the 7 stars forming the Great Dipper are similarly connected according to Mr. Proctor who proposes the name of Star-drift for this "community of proper motions" in certain regions. Star-drift has also been

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[a] ~~"It is not improbable that by tracing out the path of the solar apex in the heavens, the actual path of the sun in absolute space may be one day determined. This would, indeed, be a magnificent triumph of sidereal science; but a countless series of ages may, perhaps, elapse before its achievement will be realized."~~

Grant p. 559

His. of Phy. Astron. by R. Grant

N. 4

a. The most conclusive proof that they do not revolve round definite attracting centres, as held by Kant and Lambert, is found in the variety and irregularity of their proper motions.

Newcomb. p. 485

(See [illegible] p. [illegible])

a "The majority of the resolvable nebulae lie n[illegible]
the direction of the plane of the Milky Way, which
implies that they constitute part of this system
for otherwise the probability against the g[illegible]

noticed in several close groups, like the Pleiades, and in pairs of widely separated stars.

59 It is likely that the stars follow an irregular path,[a, fly leaf] which changes as their situation among the other stars changes, the motion which all must have to prevent their falling to a common center, being so adjusted as to keep each star from a collision with its neighbors. Such a plan might go on safely for millions of years longer, beyond which time we have as good reason for believing that the visible universe is approaching an end in its present form, as we have for believing that it had a beginning in the gaseous form, when there was neither sun nor planet.

Motion in the Line of Sight. The spectroscope now tells us whether a star, in its
5 forward progress, is approaching the earth or receding from it. In the former case, the dark lines seen in its spectrum[b] are found

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[b] "The spectrum of a star is the combination of colors which we see when we look at a bright star through a prism" Newcomb.
The fine dark lines seen in the spectrum inform

N 457 nearer the blue end of the spectrum, and in the latter case nearer the red end, than they would be if the distance of the star from the operator was a constant one. We thus find the
N 458 stars in the neighborhood of Hercules to be mostly approaching the earth, and those which lie in the opposite direction to be receding from it, in accordance with those observations from which the solar motion has been deduced. Hence we are assured of
N 457 this motion in two different ways. None of the stars are moving exactly towards us.

N 458 The stellar motions will, in the course of ages, change the brilliancy of the stars, as seen from our earth, and also give different groupings to the constellations.

<u>Distance of the Stars.</u> Were an observer to look at a distant beacon-light from one position, and then from a second position

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us of the constitution of the star, as in the case
334 of the sun (See p.) thus α Orionis is known to contain 5
350 of our elements, Aldebaran 9 &c.

The brightest, and therefore probably the hottest stars, such as Sirius, give more simple spectra than the cooler stars such as our sun, and hence the spectroscope may also indicate the age of a star.

considerably to the right or left of his former stand, he would see the light against different parts of the sky in the two positions. The more distant the light, however, the less it would seem to have moved in consequence of the observer's change of place, and, finally, it might be so far away that the same change of place would produce no displacement of the light on the sky. Now an observer on the earth sees the stars, ~~many~~ at intervals of six months, from opposite positions in the earth's orbit, the distance between which is no less than 190 millions of miles. Yet so much farther are the stars, that, with a few exceptions, this change of the observer's place produces no corresponding change in their place on the ~~stars~~ sky. In other words, a diameter of 190 millions of miles shows only as a point when viewed from the stars. The few exceptions, a score or so, are slightly displaced to the view in these half-yearly journeys of the earth, and thus is afforded the means of obtaining their distance from us. So very minute is the parallax in any case, however, for such is the displacement called, that the attempts to discover and estimate it were many and

unsuccessful before the task was at length achieved in 1838 by Bessel, the celebrated astronomer of Königsberg. The star under observation was one of the 6th magnitude in the Swan, called 61 Cygni, which Bessel chose for several reasons, and which, after 3 years of continued watching, he finally declared to have a parallax of 0".35. Subsequent investigations have established this to be a little larger, viz. 0".37. a Centauri, in latitude 60° S., is the nearest star to our system,[a] yet one counting three every second of time both night and day, would require 209,499 years to enumerate even the number of miles to this star.

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[a] Its parallax is about 1/2000 of the apparent diameter of the sun. (32′ ÷ .91″).

The distances of the stars are sometimes expressed by the time required for light to pass from them to our system. (See the "Table", p.)

"We can say with confidence that the time required for light to reach us from the most distant visible stars is measured by thousands of years." Pop. Astron. by Newcomb. p. 473.

N. 205 It is remarkable that among the 13 stars of the 1st magnitude in our latitude, less than half have been found to have any measurable parallax. In the most part, the stars with a decided parallax are not of a

N. 206 (Lockyer) conspicuous magnitude, but were judged to be comparatively near to us from their large proper motion.

The Stars are Suns and our Sun is a Star.

The stars are so very distant that not even the most powerful glasses can increase their dimensions beyond the point to which the telescope always reduces them by cutting off their radiation. This immense distance shows that they shine by their own light[a], like our sun, and they probably have their attendant retinues of planets in different stages of development, like those of our own solar system.

N. 46 The discovery of the distance of several stars by means of their parallax, has enabled us to compare our sun in brightness with these stars. We thus learn that if it were placed at their average distance, it would probably

[a] The polariscope also shows this.

N. 453 not exceed the 3d or 4th magnitude. Another
Rolfe estimate shows that, at the distance of the
46 nearest star, it would shine as a star of the
2nd magnitude, such as the pole star.

<u>Twinkling of the Stars</u>. It is only within a few years and by the aid of the spectroscope, that sufficient details regarding the phenomena of twinkling or scintillation have been recognized, by which to establish a sure theory. Prof. Respighi of Rome is the astronomer whose observations are most carefully made, and whose theory best explains the facts noticed. This observer finds scintillation due in small part to atmospheric dispersion (See p. 7), but chiefly to the existence of strata of air of different refractive power from the surrounding atmosphere, this difference arising from variations in temperature, density, and moisture. The various motions of these strata, with respect to the rays which reach the eye, also play an important part in producing scintillation. Strata thus operative are believed to be very far off, for in this case a slight difference in the indices of refraction would produce a greater effect.

phenomena — Encyclopedia —

Milner

Planets twinkle less than stars because of their disks, which, though small, cannot be so sensibly disturbed as mere points of light, such as the stars appear. In serene climates and on high mountains the twinkling of the stars is much less intense than when viewed from other situations; the stars also shine with a vivacity unknown to those positions only with a denser atmosphere.

<u>The Color of the Stars.</u> The vast majority of the stars visible to the naked eye are yellow, like our sun. Arcturus, Capella, Aldebaran and Pollux are examples of this class. Rigel and Vega are examples of white stars. Betelguese and Antares are examples of the brighter reddish stars. Most of the telescopic stars are red.

The color of over 80 per cent of the variable stars is red or orange. The spectra of variable stars show changes which appear to be connected with the variations in their light.

a p. 29

The components of a large majority of the double stars are white and of the same intensity. In many cases the color

The following are a few of the most interesting coloured double stars.

	Color of larger one.	Color of smaller one.
γ Andromedae	Orange	Sea-green
α Piscium	Pale green	Blue
β Cygni	Yellow	Sapphire-blue
η Cassiopeae	Greenish	Fine blue
A star in Argo	Pale rose	Greenish blue
" Centaurus	Scarlet	Scarlet.

29

of the two stars is the same with a different intensity, the color being, besides white, yellow, red, or bluish. When the components are of different colors, the brighter generally shows a tinge of red or yellow, the fainter of green or blue. In such cases, the light of the latter, if it is much smaller than the former, may be due to contrast only[b], but most frequently the tint of the small star remains intact when the operator has concealed the large one from his vision. See B. Eng.

The stars also vary in color, with or without corresponding changes of magnitude; thus [a] Ursae Majoris periodically changes color

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[a] "Secchi classifies the various stellar spectra into 4 types, distinguished from one another by marked differences in the position, character, and number of the dark lines. Type 1 is composed of the white stars, type 2 mainly of the yellow stars, type 3 of the brighter reddish stars, and type 4 comprises the red stars.

The colors of the stars are more noticeable with the telescope than with the eye alone (Lockyer)

[b]. See "Accidental Colors" in Nat. Phil.

from an intense fiery red to a yellow, or yellowish red every 5 weeks. (Newcomb & Holden's Astron.)

The same star, in a few cases, has been found to be of a different color after an interval, as Sirius, which the ancients represented as a red star, while now it is notoriously azure-white.

The various colors exhibited by the stars indicate differences of condition at their surfaces, as shown to be the case by spectrum analysis.

Aberration of Light. If a star is observed through a telescope for a year it will be seen to describe a minute circle in the heavens. it is known that the star's This motion is known to be only an apparent one, arising from a displacement of the star, called the aberration of light. This displacement is caused by the telescope's being carried forward with the earth in its orbit, at the same time that the stellar ray is passing down the tube. The ray, therefore, which enters the tube, say at the centre, leaves it at the eye-piece a little behind the centre, and thus takes a slanting

direction through the tube. The amount of
N. 212 the slant is exceedingly minute, since it depends upon the ratio of the earth's orbital velocity of 19 miles a second, to the velocity of light which is 186,000 miles a second.

Yet a ray thus slanted towards the eye is found to terminate in a point in the
N. 213 heavens 20" from the star's true place. This point is necessarily ahead of the point towards which the telescope is directed, but as the earth reverses its motion in space when half through its orbit, it follows that the stellar ray describes a semi-circle around the right side of the eye-piece for six months and then around the left side for six months.[a]

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[a] This circle, which is obviously parallel to the earth's orbit, is gradually foreshortened from the poles of the ecliptic to the ecliptic, until here, a star appears to oscillate along a straight line 20" on each side of its true position.

The aberration of light changes the declination of a star in Mar. and Sept., and the

earth's annual motion changes the declination of such stars as have parallax in June and Dec. These two results occur at these opposite periods for these reasons. In Mar. and Sept the earth's orbital motion is in the direction of north and south, known by the plane of the equator being edgewise to the sun at these times, and therefore the telescope shows a star north or south of its true place. In June and Dec. the earth's orbital motion is in the direction of east and west, known by the plane of the equator being sidewise to the sun at these times, and therefore the telescope shows a star east or west of its true place, giving no change of declination. In the case of parallax, a star, at any given time, is seen east or west of the position it occupied six months before, when a line joining the earth's positions in its orbit on the two dates lies in the direction

of the equinoctial points, and this happens in Mar. and Sept. when the plane of the earth's equator lies edgewise to the sun. Again, parallax causes a star, at any given time, to be seen north or south of the position it occupied six months before, or its declination to be changed, when a line joining the earth's positions in its orbit on the two dates lies in the direction of the solstitial points, and this happens in June and Dec., when the plane of the earth's equator lies sidewise to the sun.

-J. 111 The aberration of light was accidentally discovered by Bradley while he was seeking to ascertain the parallax of a star, in order to learn its distance. Knowing that parallax must change a star's declination in June and Dec. Bradley was perplexed to find that the star he was operating upon showed this change instead in Mar.

N. 212 and Sept. Not long after the explanation was sug-

Pop. Sc. gested to him by noticing the effect which the motion

Living of a boat had on a vane at the top of a small mast

186 in the boat.

Chapter IV. The Sun.

In studying the structure of the sun, astronomers generally divide it into 4 portions, as follows:

The Sun by Young p.82 — 1. The Sun's Central Mass, which includes 9/10 or more of the whole mass.

Young p.[illegible] 130; Newcomb p.237 — 2. The Photosphere, or Light-sphere, which surrounds the central mass, and is the shining, visible part.

Young p.180; Newcomb p.257 — 3. The Chromosphere, or Color-sphere, which surrounds the photosphere, and is only visible during a total solar eclipse or by the aid of the spectroscope.[a]

Newcomb p.258; Young 210 — 4. The Corona, which surrounds the chromosphere and forms the outer material of the sun. This is only visible during a total solar eclipse.

p.18 — The Central Mass of the Sun. This mass is generally believed to consist of intensely heated

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[a] A very interesting and lucid account of this modern instrument may be found in "The Sun" by C. A. Young.

gases, for the two following reasons: 1st, the low mean density of the sun, showing it to be impossible for substances to have the solid or even the liquid form to any considerable extent, and 2dly, the enormous heat at the surface, notwithstanding this is constantly radiating into the surrounding space. But these interior gases, owing to their high temperature and the tremendous pressure of the overlying portions of the sun upon them, must be very different from gases as we know them. In fact, their density and viscosity are probably so great as to keep them in a condition resembling tar or honey. It is not likely that a heterogeneous mass of this character would remain quiescent, and hence occur the eruptions and explosions which throw up to the surface the quantities of hydrogen and other gases, as learned by astronomers.

The Photosphere. This part of the sun, according to appearances, is composed of luminous clouds formed by the cooling and condensation of the metallic vapors which are constantly issuing out of the interior of the sun. The mist thus

Y. originated gathers into drops, like the mist of our
0,109 terrestrial clouds, and these rains heavily back
s again into the body of the sun. Granting that any
.211, considerable portion of the heat radiated by the sun
212 is due to such a condensation of the solar vapors,
the quantity of falling liquid must be so enormous
as to constitute more or less continuous sheets,[a] past
which the lower ascending vapors must make their
way. And since these vapors necessarily equal the descend-
ing products in weight, the former must rush up-
ward with a prodigious velocity and possibly with
occasional explosions as they crowd through the con-
tracted channels.

Y. 175 [a] "The products of condensation must always be
descending in an inconceivable rain and snow of
molten and crystallized material.

.09 "All that we can learn as to the temperature and
constitution of the sun makes it hardly less than
certain that the visible surface, which is called the
photosphere, is just a sheet of self luminous cloud, pre-
cisely like the clouds of our own atmosphere, with the
exception that the droplets of water which constitute

268 <u>Sun-Spots and Faculae</u>. Through a telescope dark spots are occasionally seen on the surface of the sun. These are believed to consist of a
176 comparatively dark mass of material sunk into
5,278 the photosphere, the cavity produced in the latter, sometimes showing as a notch on the edge of the
3, (n73) sun's disk when a large spot is passing it.
Bright streaks, called <u>faculae</u>, are generally seen around the spots, and more or less over the

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terrestial clouds are replaced on the sun by drops of molten metal, and that the solar atmosphere in which they float is the flame of a burning, fiery furnace, raging with a fury and an intensity beyond all human conception.

280 "The depth, or thickness of the photosphere is quite unknown. Nor is it certain whether it is separated from the inner core by a definite surface, or whether, on the other hand, there is no distinct boundary between them.

290 "As to the shape of the photospheric clouds, it has usually been assumed that, as a consequence of the ascending currents by which they are formed, they are columnar, their height being much greater than their other dimensions. Ref. C. A. Young.

—Return to text, p. 3, last word of 7th line from top "past."

271 whole disk of the sun. These have been shown to
173. be elevated masses of luminous matter, chiefly hydro-
137 gen, probably thrown up in eruptions. Faculae some-
106, times cover areas immensely larger than any terres-
109 trial continent, but, like banks of fog, their shape
is constantly changing. Besides spots and faculae,
the whole bright surface of the sun looks mottled,
which appearance Prof. Langley compares to the effect
which fleecy clouds scarcely distinguishable in out-
line, would produce upon the vision.[a]

269, The greatest activity, however, is centred in the
271 spots, whose rapid variations show a velocity of move-
ment that is wholly beyond comparison with even
our wildest hurricanes. In these gigantic commotions
of the solar elements gases and vapors that have be-
come cooler and duller than the photosphere from
remaining in regions above it are cast down in
157. enormous masses to a depth of several hundred.
128

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[a] Such a cloudiness would very naturally follow from the constant interchange of heat and cold which must be everywhere going on between the upper and lower strata of the solar envelope.

miles below the level of the photosphere. Some think
171, that a great eruption has thrown out this material,
174 which then settles back into the sun, as ashes thrown
out from Vesuvius settle upon the surrounding country,
172, while others are of the opinion that the dull masses
175 are carried down in a cyclone.

118 Sun-spots generally occur in groups, showing
how wide-spread the disturbance is that causes
them. Groups have been observed covering areas of
125 more than 100,000 miles square, and single spots
have been known to measure 40 or 50,000 miles in
275 diameter. Again, some are so small as to be scarcely
visible. And as they are of all dimensions, so they
are of all ages, from a few hours to several months.
118 Sometimes a large spot divides into two or more,
which appear to fly asunder with velocities of from
300 to 1000 miles an hour. This shows plainly that
there is nothing solid in their track, but that
everything tosses about as easily as clouds or as air
is borne along in the breeze and the gale. The spots
140 lie mostly between 10° and 30° of latitude on each
side of the sun's equator, which two belts are there-
271 fore the scene of the greatest activity of the body.

The reason for this is not yet conclusive.[a]

<u>Periodicity of the Spots.</u> Sun-spots increase in number for about 4½ years, and then decrease in
4.149 number for about 6½ years, there being a time every 11 years or little more when they are most abundant. Now it has been shown that the average daily excur-
154 sions of the magnetic needle increase and decrease in amount during the same intervals, E p.– and for-

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289, [a] Prof. Young says that it is easy to conceive how, in
142, more than one way, the sun's rotation might lead to the
177. distribution of the spots into these two belts. At the same time he shows that no way yet proposed is free from
149, important objections. Regarding the periodicity of the
150, spots, this seems to him to depend rather upon the con-
151, stitution of the photosphere and the rate at which the
152 sun is losing heat than upon the influence of the planets, or the fall of meteors upon the sun, as held by others. He therefore finds the periodicity more likely to be very
153. irregular. As to its effect upon the earth, other than magnetic, he asserts that it will take a much longer study of the subject in order to settle it. (Return to text 2d line from top)

~~The spots have movements of their own both in~~

this and other reasons there is thought to be no doubt that sun-spots have an influence upon the magnetism of our earth.[c]

~~latitude and longitude~~ [a] (belonging to page , 3d line from top) These movements, when combined, bear a strong analogy to the manner in which storms travel over the equatorial zone of the earth. The apparent rotary motion of some of the spots about a vertical axis also has its like in terrestrial phenomena. ("Return to text, p.10, last word on 3d line from top" "vertices &c")

[b] "The convincing evidence as to the reality of the asserted connection lies in the closeness with which, ever since we have been in possession of continuous and satisfactory observations, the magnetic curve copies that of the sun-spots." Prof. Young. p.155

No satisfactory theory has yet been framed to account p.156 for this effect of solar disturbances upon the terrestrial magnetism. (Return to text, last 2 words on p.7 "and you")

[c] "Everyone knows that the compass-needle does not point exactly north, and its divergence from the true meridian is different in different places. On the Atlantic coast of the United States, for instance, the north pole of the magnet points west of north, and on the Pacific coast east of north.

The Solar Rotation. It was long ago recognized
Y. 114 that the spots travel from the eastern to the western limb of the sun in such a manner as to show that they form a part of it, and that the sun

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It also changes continually at any particular place. One of the most noticeable of the regular magnetic changes is the so-called diurnal oscillation: between sunrise and one or two o'clock P.M., the north pole of the needle moves west in these latitudes, returning to its mean position about 10 P.M. and remaining nearly stationary during the night. The extent of this oscillation in the United States is about 15′ of arc in summer, and not quite half as much in winter; but it differs very much in different localities and at different times. Also, as Lamont has discovered, the average extent of this diurnal oscillation at any given observatory increases and decreases pretty regularly during a period of 10½ years. + + + + Occasionally magnetic 'storms' occur, during which the compass-needle is sometimes almost wild with excitement, oscillating 5° or even 10° within an hour or two. These 'storms' are generally accompanied by an aurora, and an aurora

rotates upon its axis. The period is difficult to de-
y. 133 termine from the fact that the spots have movements
of their own, both in latitude and longitude; a p. 8 neither
134 has the sun, as a whole, a single period of rotation,
but turns around more and more slowly with removal
from the equator towards the poles. a p. 11 At the former its
time of rotation has been found to be very nearly 25
days, while this is increased to 26½ days at the par-
allel of 30°. The rotation of the sun has also been de-
y. 100 monstrated by the displacement of lines in the spectra
of the eastern and western limbs of the sun.

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is always accompanied by magnetic disturbance."
("The Sun" by ~~Prof.~~ C. A. Young.) p. 157

Prof. Newcomb says of the aurora borealis, "This phe-
nomenon, though so well known, is one of which
great difficulty has been found in giving a satisfac-
tory explanation. That it is in some way connected
with the pole of the earth is shown by the fact that
its frequency depends on the latitude. In the equatorial
regions of our globe it is quite rare, and increases
in frequency as we go north. But the region of
greatest frequency seems to be, not the poles, but the

The solar spots describe curves across the sun which are alternately convex towards the upper and towards the lower limb at intervals of six months, excepting on June 8 and Dec. 8, when they move in straight lines. It is thus learned
Y. 138 that the plane of the sun's equator is inclined 7°15' to the plane of the ecliptic.

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neighborhood of the Arctic Circle, from which it diminishes towards both the north and the south. A close study of the aurora indicates that its connection is not with the geographical, but with the magnetic pole."

—Return to text, p. 9—

[a] If other proofs were wanting, this lack of uniformity in the rotation-period is a decisive one that the surface of the sun is not yet solid, like that of the earth.

The "equatorial acceleration", as the greater speed of the equatorial regions is called, is one of the difficult problems in solar physics. "Indeed, it is remarkable", says Prof. Newcomb, "that modern science has shown us more mysteries in the sun than it has explained; so that we find ourselves farther than before from a satisfactory explanation of solar phenomena."

Return to text, p. 11 [illegible] "At the former &c"

Y.280 The so-called "reversing stratum" is a
V.267 stratum of uncondensed metallic gases at the
upper surface of the photosphere, whose rays absorb
Y.282 all rays of the same refrangibility passing through
V.227 it, and thus produce the dark lines of the solar
spectrum. [b] The very slight difference in the strength
Y.84 of these lines in the spectrum of light from the
edges of the disk as compared with that from
— See a, p. 15 —
the centre ~~the light traversing the absorbing~~
~~stratum horizontally and vertically in the two cases.~~

Y.66 [a] The solar spectrum is the ribbon of shaded
colors ranging from red to violet into which, in
the well-known experiment, a sunbeam is resolved
by passing it through a prism. To the naked eye
this ribbon of colors is continuous, but examined
with a telescope or in a spectroscope (the most
V.224 essential parts of the latter are simply a telescope
and prism) numerous dark lines known as
Fraunhofer's lines from their discoverer are found
crossing it from side to side. These lines were
more or less a mystery for nearly half a century,
but their explanation was easy, when once seized

Y. 84. has led to the inference that these absorbing gases
280 or vapors also fill the interspaces between the
photospheric clouds, being in fact, the material
which by condensation forms the clouds, and that
within these interspaces the principal absorption
therefore takes place.

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upon. The method of it is as follows: The spectrum
Y. 89 of the ~~white~~ light used in experiment is con-
(glowing solids or liquids give continuous spectra; glowing gases, except at great pressures, give discontinuous spectra)
tinuous, or not interrupted by dark lines. But by
passing this light through a flame colored with
any vapor, as when a solution of soda is converted
into vapor in the flame of a Bunsen gas-burner,
changing it from blue to an intensely yellow color,
N. 227 a pair of dark lines appears in the spectrum in
place of the two yellow ones which would have been
given by the sodium flame alone. (These yellows
Y. 70 take the shape of lines only because the spectroscopic
slit through which they pass to the prism is itself
a line which is the best form to give the spectrum
in order to prevent overlapping of the different
grades of color.) These two yellow lines form the spectrum
of no other gas, and the spectra of no two gases are the

p. 83 It follows that if the reversing rays are extinguished by those photosphere rays which match them in refrangibility or spectral tint, that if we could isolate the former from the latter the reversing stratum would give a spectrum of bright lines. They are thus isolated at the limb of the sun where, as already mentioned, we view the reversing stratum as well as the other solar envelopes, in a horizontal direction.

p. 84 All light above the photosphere is, however,

86 hidden by the intense glare of our atmosphere near the sun's place, and hence the

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same, but the numbers and colors of the slit-images or spectral lines (elementary rays) are different in every case. Hence when the corresponding lines are found dark in the solar spectrum, the name of the gas which produces them is known. More than twenty elements have thus been discovered in the sun,

p. 87 among which are the following well-known metals, viz., iron, manganese, nickel, cobalt, sodium, copper and zinc. This agreement of solar and terrestrial metals strengthens the belief that the sun will sometime cool off into a body similar to our earth.

238 invisibility of the chromosphere and corona under ordinary circumstances. When, however, at a total eclipse of the sun, the moon has just covered the sun's disk, "through the whole length of the spectrum, in the red, the green, the violet, the bright lines flash out by hundreds and thousands, almost startlingly; as suddenly as stars from a bursting rocket-head, and as evanescent, for the whole thing is over within two or three seconds. The layer seems to be only something under a thousand miles in thickness, and the moon's motion covers it very quickly." (Prof. Young. p. 83)

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and that our earth was once a shining, gaseous body like the sun.

228 Since an element must always be in the form of gas or vapor to produce a discontinuous or lined spectrum, ~~and hence~~ the spectroscope can give us no information of the chemical constitution of bodies in the solid or liquid state. But though thus limited, the instrument is an immense acquisition to science. The character of this acquisition can be no better expressed than by recalling Prof. Young's remark that the study of spectra has added some such reach to our physics and chemistry as the telescope brought to vision. (Return to text, p. 14, 6th line from top, "The very slight sc")

a "The sun being a globe surrounded by an atmosphere, the rays which emanate from the photosphere in a horizontal direction have a greater thickness of atmosphere to pass through than those which strike out vertically; while the former are those we see near the edge of the disk, and the latter near the centre." (Newcomb.) p. 24

(Return to ~~text~~ p. 13. top)

<u>The Chromosphere.</u> This is an envelope of
Y.18, uncondensible gases, mainly hydrogen, lying above
75, the photospheric clouds, and related to them some-
19, what as the air and clouds of our earth are related
to each other. This envelope has the appearance of
a sheet of fire covered with minute tongues and
60, filaments of flame, "as if," to quote from Prof. Young,
"countless jets of heated gas were issuing through
vents and spiracles over the whole surface, thus
clothing it with flame which heaves and tosses
like the blaze of a conflagration." The apparent
Y.202 diameter of this sheet shows its average thick-
ness to be about 5000 or 6000 miles. "The chromo-
sphere is of a vivid red color, whence its name,
Y.160, the redness being caused by the great amount of
hydrogen in the blazing material. Here and there
17, masses of this hydrogen mixed with other sub-
16c stances rise to tremendous heights, where they
float like clouds, or are torn to pieces in the
wild encounter of opposite currents. These masses
Y.182 have received the name of "prominences" or
"protuberances," a name which gives one no idea
181 of their wonderful beauty and interest. There are

Y. 204, two kinds of prominences, the cloud-like and the
197, eruptive. The former closely resemble our terrestrial
204, clouds, and seem to be caused by the lighting up
207, of material before invisible. The eruptive prominences
262 seem to be thrown up from the chromosphere, rising
209 with a velocity sometimes as great as 150 miles a
second. This is 5400 times faster than a hurricane
on the earth that tears up trees and carries build-
ings before it. Sometimes the eruption continues
for days, the ejected vapors, which often rise to
207. heights of 20,000 and 30,000 miles, and sometimes
262 much higher, forming masses thousands of miles
in extent, and then falling back on the chromo-
206 sphere. Solar prominences are of every imaginable
shape and very brilliant and beautiful, but, like
terrestrial clouds and flames, they change rapidly
Y. 209 both in form and luminosity.

252 *The Corona*. The corona is an irregular
Y. 178, 17, halo of light seen around the black disk of the
moon when it covers the sun in a total solar
254 eclipse. This light is now known to belong to the
sun, and an examination of it seems to show
234 that it proceeds in great part from a glowing gas,

and also that much of it is reflected from a fine
259 mist or smoke.[a] The great comet of 1843 passed
through at least 300,000 miles of corona, with a velocity of nearly 350 miles a second, and came out without suffering delay or damage, apparently. This fact proves the corona to be very much rarer than our atmosphere is at heights of from 50 to 100

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[a] This is Prof. Young's statement. Prof. Newcomb
260 says, "The corona probably consists of detached particles partially or wholly vaporized by the intense heat to which they are exposed. A mere dust-particle in a cubic mile of space would shine intensely when exposed to such a flood of light as the sun pours out on every body in his
259 neighborhood." Prof. Newcomb urges two reasons against the gaseous formation of the corona: one is, that it must be hundreds of times lighter than hydrogen to comport with gravitation on the sun, which is 27 times as great as on the earth. The second reason is the uninterrupted passage of the comet mentioned in the text.

miles, for shooting stars entering this upper atmosphere with a velocity only of from 20 to 40 miles a second are instantly and completely turned to vapor.

According to observers, the corona varies
Y.230 greatly at different times, in form, color, and brilliancy. Sometimes it is of a uniform breadth, sometimes it sends forth one or several long streams of different lengths, and it is often divided up by
Y.179 dark spaces and overlapping masses of light. All this is what we should expect from thin masses of gas and dust exposed to raging fires that blaze
Y.17 beneath them. The corona is generally beamy, of a pearly-white color, yellowish, or even red, and fades gradually from the base into the outer darkness. It rises from 100,000 to 300,000 miles above the surface of the sun, and its highest
Y.18 portions sometimes reach even a million miles.[a] It can only be studied during the few minutes of a total eclipse, in all not more than 8 days
[illegible] in a century, and hence a knowledge of it can

.266 [a] Father Secchi says "No doubt it extends yet farther, and it may well be connected with the zodiacal light."

only be gained by slow degrees.

Although the photosphere, chromosphere
and coronal atmosphere differ, as we have seen,
p.294, yet they are not entirely separate and distinct.
All the gases are found together in the inter-
295 spaces of the photospheric clouds, the coronal gas
and the hydrogen of the prominences being in-
deed most conspicuous and abundant right in
the photosphere and reversing layer. The solar
movements are constantly diffusing these mate-
rials, while at the same time they are constantly
p.265 moving under the influence of the solar gravita-
X tion, which implies a constant thinning of the
parts upward, according as we find them.

<u>Distance of the Sun.</u> This distance ~~of the~~
p.200, ~~sun~~ probably lies between 92,200,000 and 92,700,000
194, miles.[a] There are various methods of determining
175, this distance, the most celebrated of which is by
transits of Venus over the face of the sun. The sub-
stance

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[a] This statement is from Prof. Newcomb's "Popular Astronomy."
Prof. Young says in a note to his recent edition of "The Sun"
"The solar parallax cannot differ much from 8.80", corre-
sponding to a distance of 92,885,000 miles."

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This ratio is obtained from Kepler's 3d law by the following proportion: $365.26^2 : 224.70^2 :: 1^3 :$ the cube of Venus's distance from the sun, or to .37836, the cube root of which is .723. Then if Venus is .723 as far from the sun as the earth is the latter must be .277 farther from the sun, which divided into .723 gives 2.61.

of this method is as follows: two observers take
177 their stations in opposite hemispheres, the northern and the southern, to look at Venus as she passes by the sun. The lines along which they
1.27 look will therefore cross at Venus, and proceeding to the sun show Venus traversing his disk along two tracks. The interval between these tracks, reckoned in miles, is as many times the distance between the observers as Venus's distance from the sun is times her distance from the earth, or 2.61 times. a fly leaf The same interval, reckoned in seconds of arc, is equal to the distance of the sun's centre from the nearer track subtracted from the distance of his centre from the farther track. Hence the linear value of 1" of arc is found by dividing the number of seconds into the number of miles, giving about 450; that is, 450 miles of the earth's diameter, seen from the sun, measures 1" of arc on the heavens; the earth's radius of 3959 miles must therefore measure as many seconds as 450 is contained times in 3959 or 8.80". This angle is called the <u>sun's horizontal parallax</u>, which being

found, it is easy to compute how far from the sun the earth must be situated for its radius to equal 8.80" of arc.

But this statement gives one no idea of the work that has to be done, both in observing the transit and in figuring up the results. In reading of all this, it is interesting to learn to what perfection the instruments employed have been brought, such

N. 186 as reflectors that do not vary 1/100,000 of an inch from flatness, micrometers that divide an inch into

Mitchell 80,000 equal parts, and goniometers that measure celestial arcs no larger than a thousandth part of

Science a second, or 1/1,360,000 part of the apparent diameter

[illegible] of the sun.[a] It is still more interesting to note the accuracy which the human mind has reached, and with what patience men can work at problems that often require years for their solution.

The Sun's Light and Heat.

Sunlight so far exceeds in intensity the most powerful artificial light that the latter

Y. 240 appears only as a black spot against the unclouded sun. -a p. 23-

We have the results of various experiments

[a] Add photographs of the sun taken in the 1/10,000th part of a second of time. Janssen Pop. Sc. Mon. Feb. 1883

-hen light is made to enter the spectroscope alternately
from the advancing and retreating limbs of the sun, a
line due to absorption within the sun appears to trem-
ble, as the result of slight alternately opposite displace-
ments. But if the seat of the absorption be in our atmo-
sphere, the line maintains its position in spite of the
oscillation of the image upon the slit of the spectro-
scope. It is thus determined whether the absorption of
solar rays takes place at the surface of the sun or
that of the earth.

— Return to text, left line 22 —

determining the amount of heat radiated by the solar orb. One of these, according to
18 Prof. Young, shows the solar blaze to be at least 7 or 8 times as intense as the hottest furnace, and sufficient to melt a shell of ice 10 inches thick over the whole surface of the sun every

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[a] There is a marked diminution of the sun's light at
1.245, the edges of the disk caused by the absorption of
248 a portion of the rays by the solar atmosphere. This absorbing envelope has usually been identified with the "reversing stratum", but according to a theory lately proposed, the absorption is produced by something like smoke. The strong point in the theory is the *selective* action of the reversing gases, producing bands and lines in the spectrum, whereas the absorption with which we are now dealing weakens all the rays pretty much alike. Of this veil of
29/3 "smoke" Young says "It is so obvious, on reflection, that something of the sort must accompany the photosphere, that it is surprising that the idea has not been thought of before." (See pg beg.)

second of time. The earth intercepts about
y 256 1/2,200,000,000 of this enormous heat, receiving,
during the year, according to careful estimates,
such an amount as would melt, on an aver-
y 241 age, 3.62 inches of ice per a day over its whole
surface. Part of this heat is absorbed by the
atmosphere, which also prevents the radiation
of a large proportion of heat from the earth, thus
keeping it much warmer than if there were
y 262 no atmosphere. [a]

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[a] "By the comparison of observations made through varying thicknesses of air, Langley shows that the atmospheric absorption tells most upon the light of high refrangibility; so that, to an eye situated outside the atmosphere, the sun would present a decidedly bluish tint."

Lord Rayleigh. Popular Science Monthly. Oct, '84.

"It has been proved that the heat which the earth receives from the sun is prevented from passing away again into space so rapidly as it otherwise would, by the aqueous vapor present in the atmosphere." Guillemin.
This vapor does not exceed, in amount one per cent of the

The solar light and heat are nowhere
Y.252 manifest in their passage through the
celestial spaces, but make themselves felt only
when they reach the earth or other material body.

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whole atmosphere.

The condition of the sun maintains a constant vibration among its particles, which vibrations are communicated to the ether of space, and
Y.251 produce the effects called light, heat and chemi-
cal action, according to the surface which receives
V.505 them. It has been a much vexed question how the sun keeps up its vast supply of heat, it being pretty certain that it has radiated the present supply, or even a greater, for several millions of years in the past. It is known to-day, however, that the heat generated by the contraction
V.507, of his mass, which contraction follows from his
508 cooling off, will very probably maintain the sun at his present temperature for several millions of years longer. But such a contraction must have gone on from the beginning of the solar system, and thus we can trace the sun's history
V.509 back to a time when his globe filled the whole

Size and Mass of the Sun. The dimensions of the sun are far too great to be grasped by the human imagination, whether expressed in figures or by comparison with other well-known estimates. In figures, the
Y 278 sun's diameter is about 866,000 miles, showing his vast circumference to be as far from his

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space now occupied by this system, and formed a chaotic mass of gas, as was believed to be the sun prior to the admission of the contraction theory. In whatever way the planets may have been shaped out of this mass, it is certain that they all once existed in a fiery state, out of which they have been slowly contracting and cooling for an indefinitely long period of time. Thus a solid crust has formed over the
N. 573 smaller bodies, while the great masses of Jupiter and Saturn are still hot on the outside, and would appear self-luminous but for the clouds and vapors which hide their surfaces from our view.

a 98 — Return to text, p. 25 — "But solar light &c" —

The temperature of the inky-black ether
Warren pervading these spaces is estimated to be 200° below zero. — Return to text, p. 25, 3d line from top "but makes &c".

centre as a circle 190,000 miles beyond the moon is from the centre of the earth.

Y.278 The sun's mean Apparent Diameter is 32′. This diameter varies with the varying distance of the sun from the earth and thus affords the Loomis means of determining the form of the earth's orbit. The numbers 967, 1000, and 1034 represent the Guillemin solar diameter at the sun's greatest mean, and least distances from us.

The sun's Mass, known by his attractive energy on the earth, is 330,000 times the earth's.[a]

Y.278 The sun's Volume is 1,305,000 times the earth's, which divided by his mass, shows his Density to be only about ¼ of the earth's.

Y.48 The sun's Gravity is more than 27 times the earth's. As an illustration of its effect, a man weighing 150 pounds on the earth would weigh nearly two tons on the sun, and would

Y.48

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[a] See page 11 showing the manner in which the earth's attraction on the moon was obtained from the moon's orbit. In the same way the sun's attraction on the earth has been obtained from the earth's orbit.

be unable to stir.[a] The sun's gravity retains the earth in its orbit with the same force as if the two bodies were joined by a web of the heaviest telegraph wires, nine to each square inch of the whole sunward hemisphere of our globe. (Young.)

The sun's Constant Force displayed on the earth is equal to 543,000,000,000 engines of 400 horse-power each, working day and night.[b] ~~earth receives only 1/2,200,000,000 part of the whole force of the sun~~ This force manifests itself on the earth in the winds, the tides, aerial and marine currents, evaporation of the surface waters, a gradual modification of the geological strata, and the growth of vegetable and animal life.

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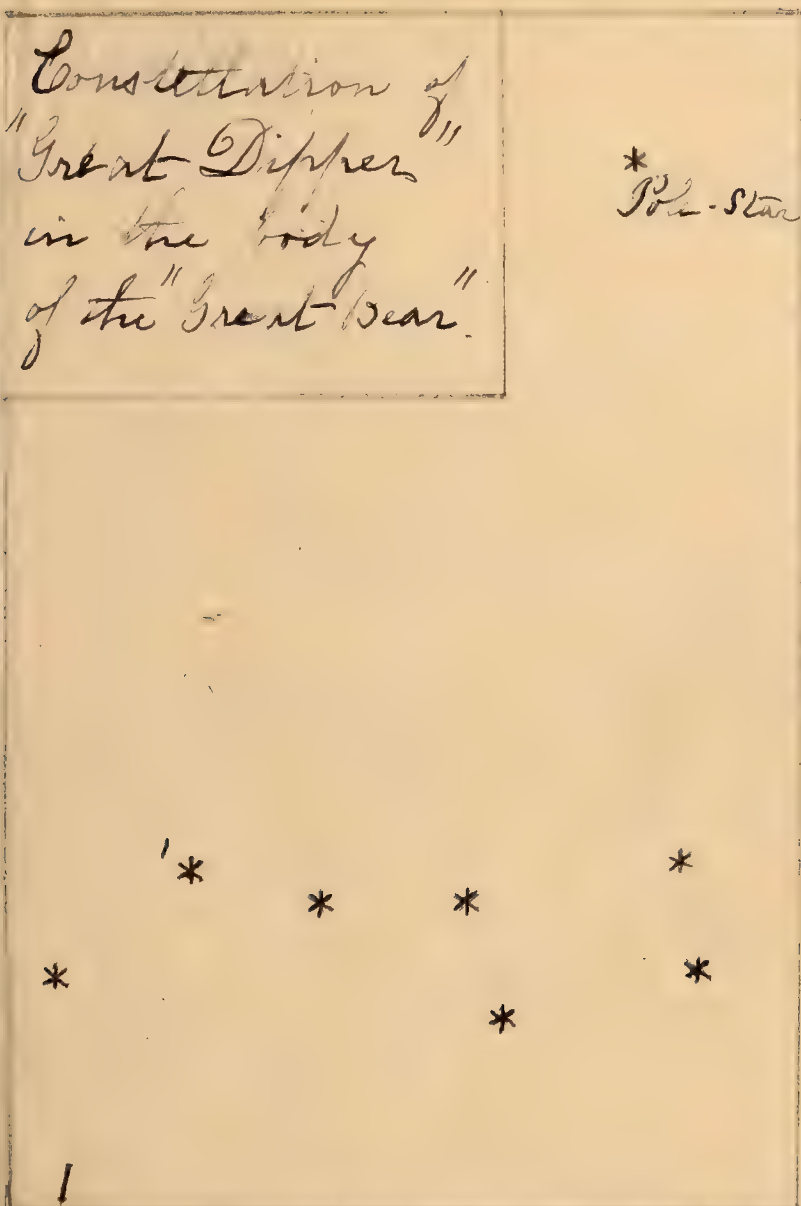
[a] See page 58 for the proportion which gravity bears to different celestial bodies.

[b] "The mechanical equivalent of the solar radiation at the sun's surface, continuously acting, is 109,000 horse power per square meter; or 10,000 (nearly) per square foot." Young.

1



A double sun, one revolving about the other. Light which travels 185,000 miles a second, takes 47 years in coming from the Pole-Star to the Earth.

1. Double sun, one revolving about the other.

2

Constellation of the "Great Bear."

11.

Star "ta" in this constellation is composed of a large white star, and a small one of ruddy purple.

Magnificent star in constellation "Auriga" or the "Waggoner." of a bluish color.

Beautiful star in the constellation "Lyra", 38 times larger than our sun. And our sun, if it-

4

Observation of a star in this constellation led to the discovery of the aberration of light.

In May, 1866, a star of the tenth magnitude in this constellation, suddenly increased in size and

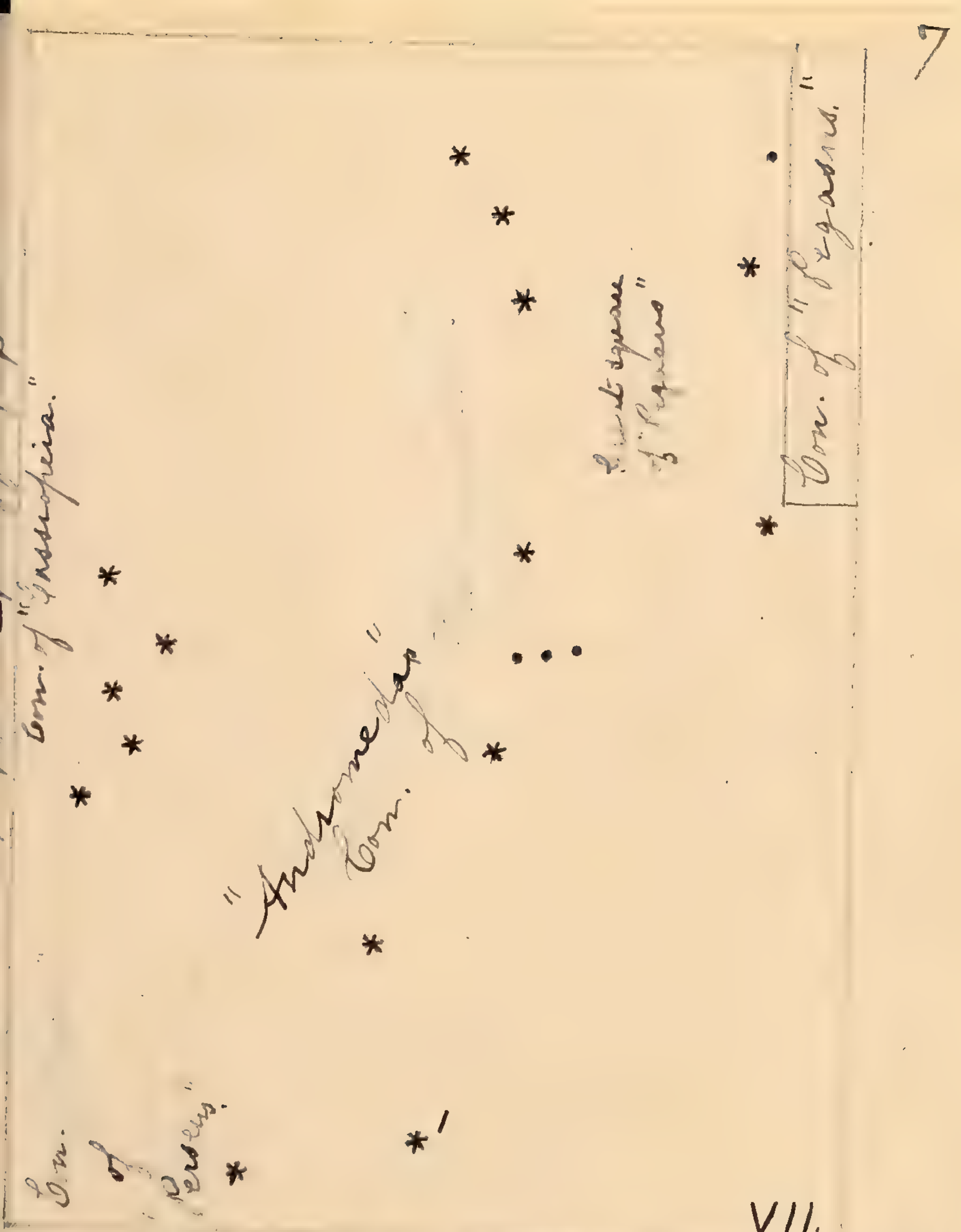
5

Con. of "Hercules."

VI.

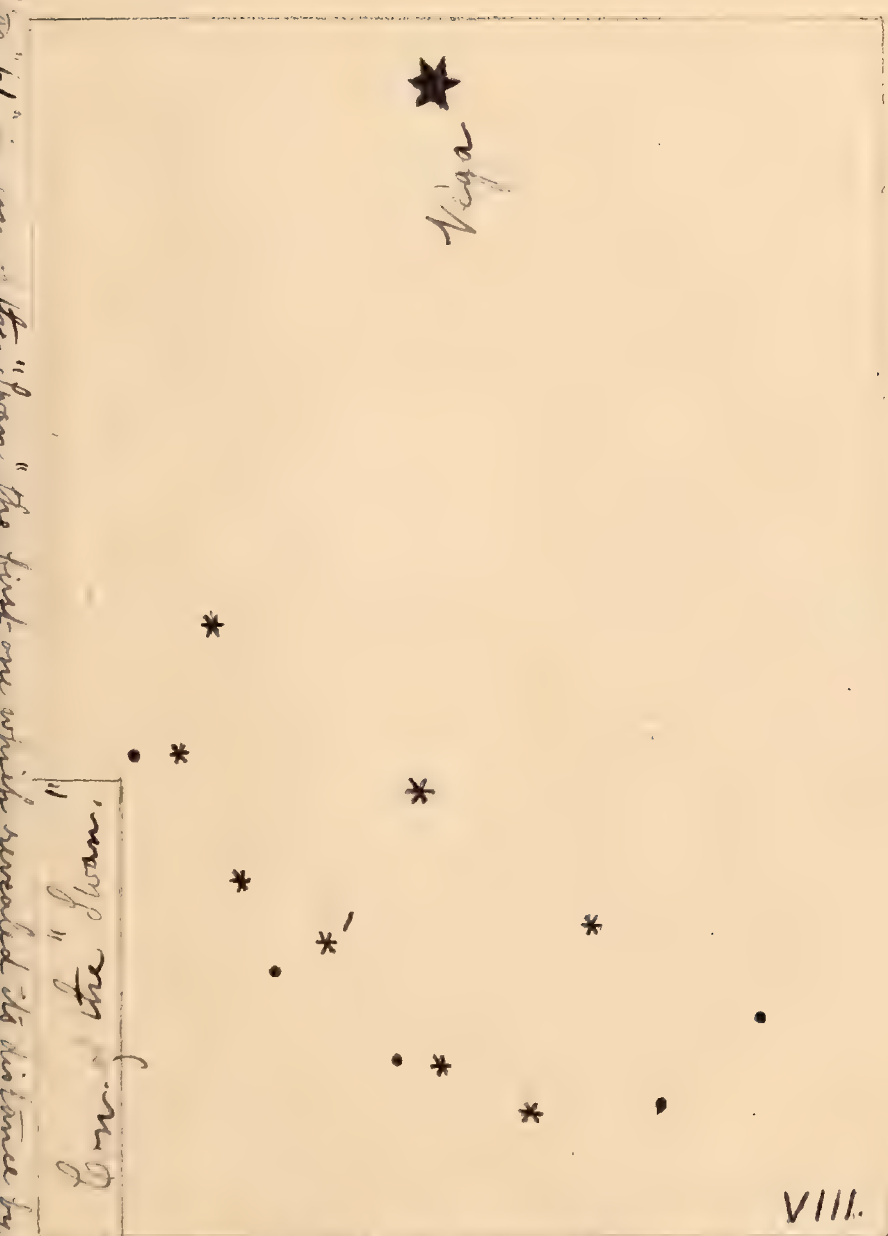
It is towards one of the stars in "Hercules" that sun and his system of planets is travelling at rate of about five miles a second.

7



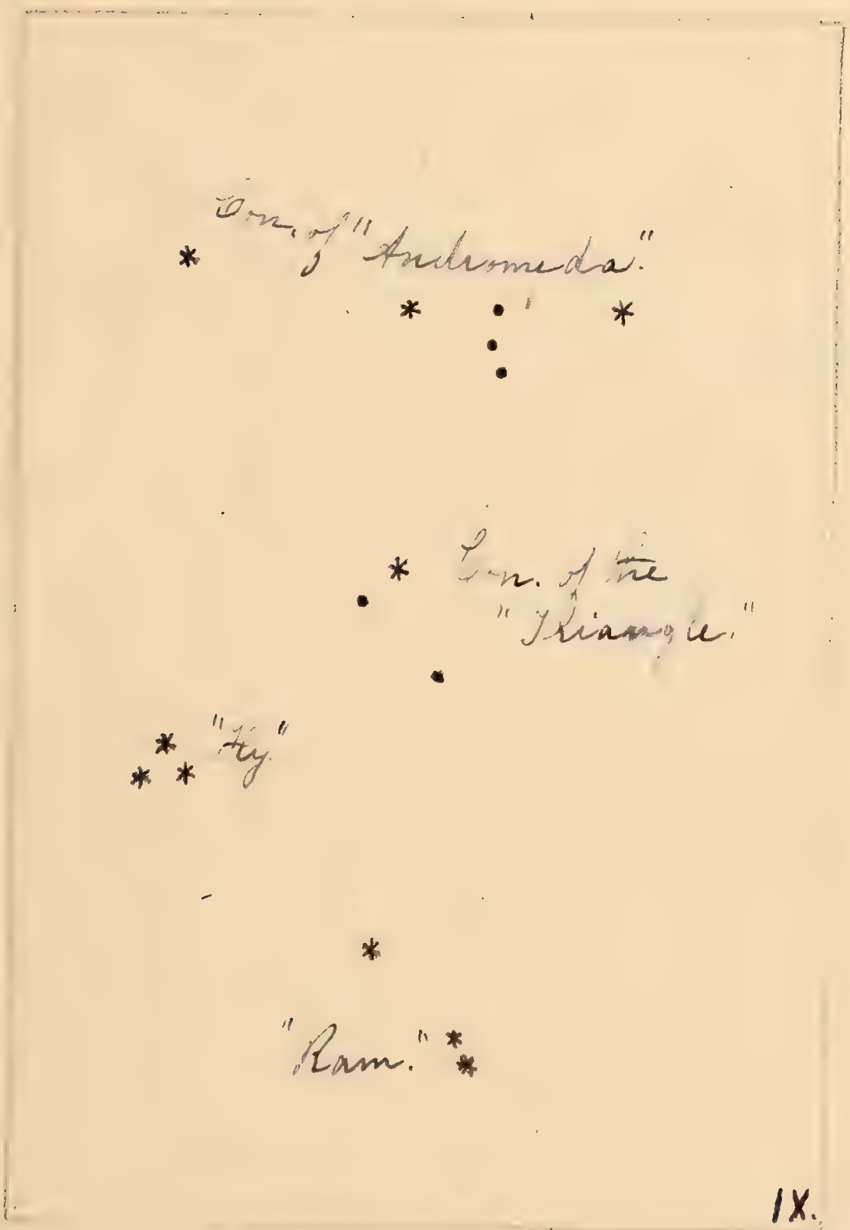
VII.

1 Star "Algol" in the head of "Medusa", a variable
changing continually from the 2nd to the 4th mag-
de and back again; accomplishing this decrease
increase in about eight hours.



1 Star "Arided" of the "Swan" lying in the bank of the "Milky Way."

Star "61" in con. of the "Swan", the first one which revealed its distance by par-

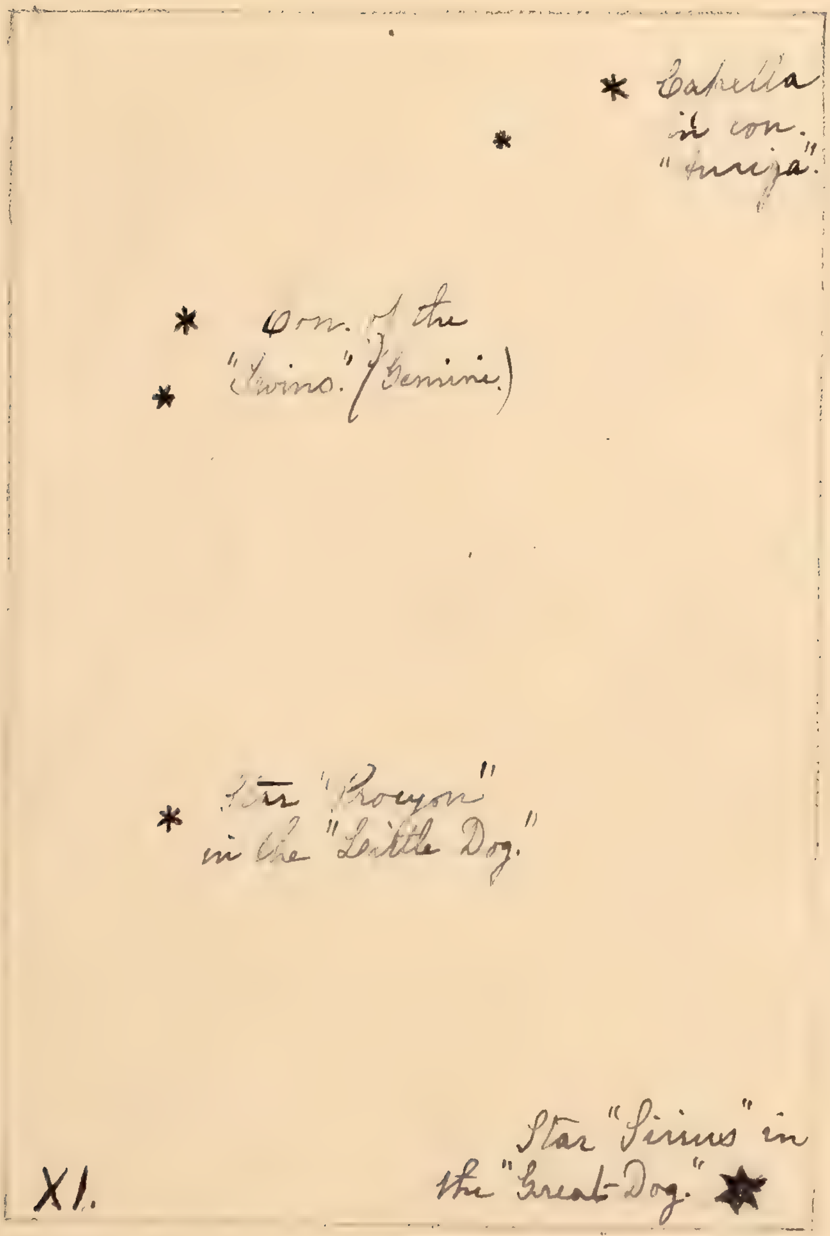


IX.

E-n. of the "Bull."

Star "Alcyone" at the centre of the "Pleiades" declared to be the grand centre round which our solar system is revolving in an orbit requiring 18,200,000 years to complete one revolution.

11


Capella in con. "Auriga".
Con. of the "Twins." (Gemini)
Star "Procyon" in the "Little Dog."
Star "Sirius" in the "Great-Dog."

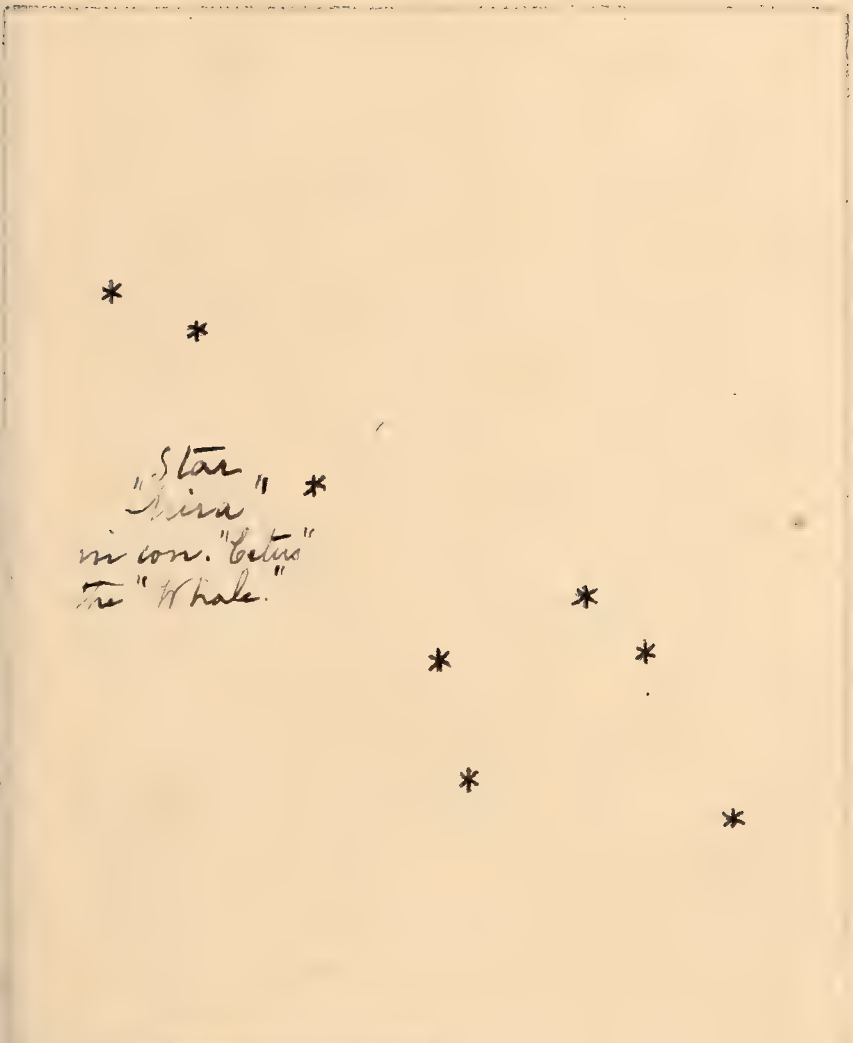
XI.

"Orion", richest of all the constellations.

XII.

1. An immense nebula.

Rigel is a very beautiful double star, composed of a white and a blue sun.



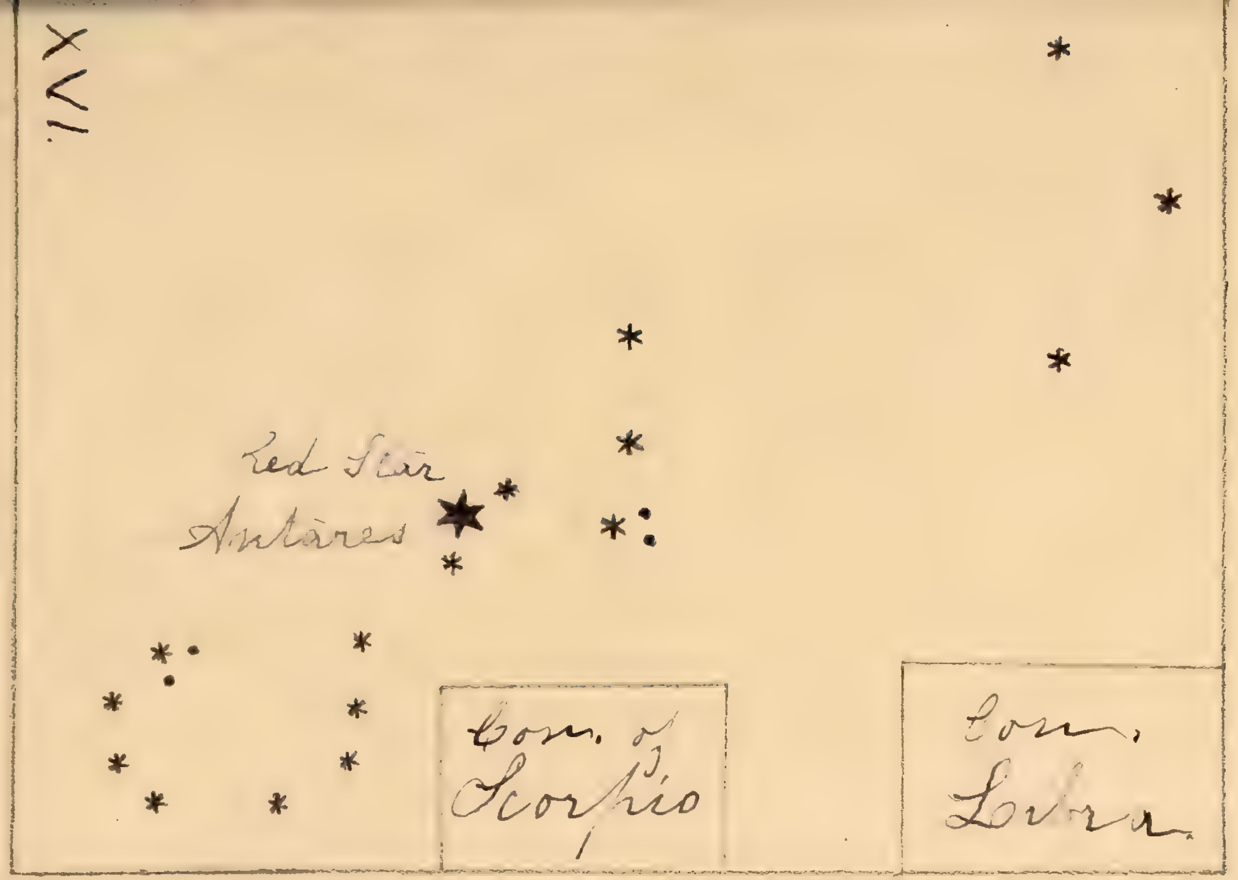
Con. "Cetus" or "The Whale."

XIII.

14

15

16



XVI.

Chapter XX.

The Constellations.

The Zodiacal Constellations.[a] The zodiac is the region of the heavens within which the apparent motions of the sun, moon, and all the greater planets are confined. This region or belt extends 8°[b] on each side of the ecliptic, and is divided into 12 constellations, called the zodiacal constellations. The names of these are as follows, beginning with the one which the sun anciently entered at the vernal equinox:

Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, Pisces.

1. Aries, the Ram. Declination 20° N. Longitude 38°[c]. Aries is easily known by its three principal

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[a] In studying the constellations, it is better to begin with those which are constantly above the horizon, or the northern circumpolar, looking first for the Great Dipper, whose pointers (See Ursa Major, p.) always lead to the North Star.

[b] In other words, this is the greatest inclination of the orbits of the bodies mentioned, to the plane of the ecliptic.

[c] These figures refer to the centre of the constellation, or thereabouts.

stars following a crooked line, as seen in Plate IX. The two upper and brighter stars lie in the head of the Ram, and are about 4° apart. A line extending from the Pole-Star through the most eastern[a] star in the W of Cassiopeia passes beyond to the bright star Almach in the left foot of Andromeda, and the same distance beyond this to the head of the Ram. The triangle seen in the Plate lies between the latter and Almach. The three little stars called the *Fly* lie just above the back of the Ram.

2. *Taurus, the Bull*. Dec. 17° N. Long. 68°. Taurus includes the two remarkable clusters known as the *Pleiades*[b] or "seven stars" and the

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[a] We have seen (p. 120) that the circumpolar constellations move around the Pole-Star in a direction contrary to that in which the hands of a clock move. The eastern part of a constellation is therefore the rear part in this motion.

[b] The ancients divided the year into two portions marked by the presence and the absence of this cluster in their sky, it being below the horizon at night-time for nearly half a year, and above the other half.

Hyades. The Pleiades really consist of a large number of stars, only six of which are visible to ordinary eyes. The principal stars of the Hyades form a V, with red Aldebaran, the "Bull's eye", at the left extremity. The two stars high up on the left (See Plate X) mark the tips of the Bull's horns. Near the right one is the Crab nebula, so named from its shape. A pair of small, contiguous stars lying quite near Aldebaran have received the name of a double, though they are not classified as such they are so wide apart when highly magnified.[a] The Pleiades lie nearly due east from the Ram's head. (See "Motions of Groups of Stars" p. 154)

3. Gemini, the Twins. (See Plate XI). Dec. 23° N. Long. 105°. This constellation, which is in the form of a long and irregular quadrilateral, begins at the left of the Bull's horns, and stretches eastward

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a. α Capricorni and ϵ Lyrae are similar doubles.

b. Prof. Piazzi Smyth has determined the fact that the southern face of the pyramid of Gizeh was directed to the Pleiades at its midnight culmination in 2170 B.C. while the northern face was directed to the then Pole-Star, α Draconis.

to two bright stars called Castor and Pollux. South of these is the bright star Procyon,[a] in Canis Minor, the Little Dog. (See "Uranus" p. 7)

4. Cancer, the Crab. Dec. 22° N. Long. 128°. The most noteworthy object in Cancer is Praesepe, the Beehive,[b] a group of stars plainly visible as a nebulous mass or milky patch of light in a clear, moonless sky. Cancer contains no conspicuous stars. It lies between Gemini and some stars arranged in the form of a sickle in Leo.

5. Leo, the Lion. (See Plate XIV) Dec. 15° N. Long. 158°. Leo contains the bright star Regulus, which, with five others, forms a sickle, Regulus being the handle. This star is also the heart of the Lion, the curve of the sickle forming his head.

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[a] This star has been found to move around an invisible centre 1" distant, which is probably the centre of gravity of the star and an invisible satellite.

[b] The ancients called this group the Manger, out of accommodation to two stars of the 4th magnitude about 2° distant, which they named the Asses.

An ordinary night-glass resolves this patch entirely into stars.

A straight line passing from the Pole-Star through the Pointers will lead to the Lion, just east of the sickle. Between the sickle and two stars on the north in one of the Bear's feet, is the small constellation of Leo Minor, the Little Lion. A faint triangle south of the sickle forms the Sextans.

6. Virgo. (See Plate XV). Dec. 0° Long. 195°. The principal stars of this constellation form a very open Y, with the bright and conspicuous star Spica[*] at the bottom of the figure. The star at the western extremity of the Y lies due south of a bright star in the tail of the Lion, called Denebola. Between the same extremity and the handle of the Great Dipper lie Berenice's Hair and the Hunting Dogs of Boötes. Some faint stars in the former take the shape of

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[*] The Arabs called this star the unarmed because of its solitariness, there being no visible star near it but one of the 5th magnitude. They also conferred a name upon the upper part of the Y, calling it the Retreat of the Howling Dog. Spica is situated in the zone traversed by the moon, and therefore serves for finding the longitude at sea, which is known from the distance between the two bodies,

a small figure not unlike a y.[a] The latter constellation, which lies farther to the north, contains a famous spiral nebula, and also the famous star Groombridge 1830, known to be travelling through our firmament at the rate of 200 miles a second. (See p. 151). Only one distinct star is seen in this region, the solitary Cor Caroli,[b] or Heart of Charles. To the right of Spica, but lower down, is the small constellation of the Crow, its 4 conspicuous stars forming an uneven quadrilateral, whose base rests on the back of the long horizontal constellation Hydra, the head of which (also marked by a quadrilateral) is just south of Cancer and east of Procyon. Southwest of the sickle in Leo is a star standing alone (called the Solitary One by the Arabs) which marks the heart of Hydra. A row of 3 or 4 small stars on the right of the Crow forms the Crater. Virgo is rich in nebulae. There is a

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[a] Coma Berenices is a close, irregular group of very small stars, quite different from anything else in the heavens.

[b] The quadrilateral formed by Arcturus, Denebola, Spica, and Cor Caroli is called the "Diamond of the Virgin."

fine one a little to the west of Spica. The star at the fork of the Y (γ) is double, with a period of 185 years. The equator crosses this constellation close to this star. A line extending from the Pole-Star through the middle star of the handle of the Great Dipper leads to Spica.

7. Libra. Dec. 12° S. Long. 227°. Libra has no stars which will attract attention. The four ordinary ones represent the Scales, with a faint one for the fulcrum on the right. β Librae, the most northern of the Scales, is of a deep blue color, a rare occurrence among the isolated stars.

8. Scorpio. (See Plate XII) Dec. 30° S. Long. 245°. Scorpio is the most picturesque constellation in the sky, and very conspicuous. It contains Antares, a reddish star of nearly the first magnitude, which is composed of two suns, a red and a green one. (See "Colored Stars" p. 15). Unlike most of the other constellations, Scorpio really shows some resemblance to the object whose name it bears. At the same time the figure is not unlike a boy's kite with a long tail, as frequently described. The ecliptic passes between the two upper stars of the three conspicuous ones

on the right. The large star in the Plate shows the place of Antares. A faint collection of stars south-west of Scorpio forms Lupus, the Wolf.

9. Sagittarius. Dec. 30° S. Long. 275°. This constellation contains a large collection of 2nd magnitude stars. It may be known by 5 stars, forming an inverted dipper, called the "Milk-dipper," 3 of which lie in the Milky Way and 2 on the east of it. Sagittarius lies due east of Scorpio.

10. Capricornus. Dec. 20° S. Long. 312°. Capricornus is marked by three pairs of stars arranged in a triangle.* It is one of the least striking of the zodiacal constellations.

11. Aquarius. Dec. 12° S. Long. 335°. Aquarius is not easily discerned, as its brightest stars are only of the 3d order. Its eastern part, in which several faint stars are seen grouped together in three or four places lies due south of the Great Square of Pegasus, with the western part of Pisces; a sprinkling of 7 small stars

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* The top star in the upper pair on the west (α, β) will be seen to consist of two, a larger and a smaller one, if one observes it very carefully.

about equally distant from each other) lying between. There are 5 double stars in Aquarius of the various colors of white, yellow, and blue[1]. South of Aquarius is a single bright star named Fomalhaut, which lies in the head of the Southern Fish, (not to be confounded with the constellation Pisces.) A line through the right hand stars of the Great Square of Pegasus leads south to this star. It is the most southern star of the 1st magnitude seen in our latitude. Fomalhaut is visible for 6 weeks in Oct. and Nov.

12. Pisces. Dec. 10° N. Long. 10°. Pisces is a loose assemblage of small stars difficult to trace, occupying a large triangular space in the heavens. There are 7 double stars in Pisces of the colors white, violet, yellow, red, and blue. Pisces stretches southwest from the head of the Ram through the 7 stars mentioned in Aquarius.

Northern Circumpolar Constellations.

1. Ursa Minor, the Little Bear, called also the

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[1] In mentioning these objects, reference is always had to the more remarkable of their kind.

- Little Dipper. (See Plate). Dec. 78° N. Long. 232°.

The Pole-Star[a] belongs to this constellation, forming the tip of the Bear's tail. This star is double. β and γ are known as the "Guardians of the Pole."

2. Ursa Major, the Great Bear. (See Plate). Dec. 55° N. Long. 158°. The Great Bear contains 7 prominent stars, known as the "Great Dipper." The two most remote from the handle always point to the Pole-Star, and are hence called the "Pointers." They are 5° apart. The star at the junction of the handle has been growing dimmer for a century. The middle star of the handle has a minute companion almost touching it, sometimes called "Jack by the middle horse." The former star is double, consisting of a small one revolving around a larger one. 35 stars can be seen by the naked eye in the

---

[a] Called also Polaris. "This star has not always been, nor will always continue to be our cynosure: at the time of the construction of the earliest catalogues it was 12° from the pole — it is now only 1° 24', and will approach yet nearer, to within half a degree, after which it will again recede, and slowly give place to others which will succeed in its companionship to the pole."

Herschel's Outlines of Astron. p. 572.

Great Bear; between 3 and 400 with the telescope.[a]

3. <u>Cassiopeia</u>. (See Plate I) Dec. 65° N. Long. 10°. Cassiopeia is on the opposite side of the Pole-Star from the Great Dipper, at about the same distance. The constellation can be readily recognized from its resemblance to the letter W, the open part of which is invariably turned towards the Pole-Star. There are 3 double stars in Cassiopeia of the colors yellow, purple, white, and blue. (See "New Stars" p. 149) The southern half of Cassiopeia lies in the Milky Way.

4. <u>Draco, the Dragon</u>. (See Plate IV Dec. 60° N. Long. 255°.

5. <u>Cepheus</u>. Dec. 70° N. Long. 330°. These two constellations occupy the region between the W of Cassiopeia and the handle of the Great Dipper and

---

[a] All the stars in the Great Dipper except Benetnasch (end one in the handle), and Dubhe (farthest top one in the bowl) have a common motion somewhat in the direction of Thuban (See "Motion of Groups of Stars" p. 154; see the map for Thuban, α of Draco), while the two named have a motion nearly opposite. In 26,000 years the end of the Dipper will therefore have fallen out so that it will hold no water, and the handle will be broken square off at its middle star (Mizar).

contains no noticeable stars. 3 bright stars lying about halfway between the two Dippers mark the tail of the Dragon. A curve of bright stars winding round the Little Dipper and then towards the south, leads to his head. This is known by an irregular quadrilateral of 4 bright stars, both the longest and shortest sides point to the Pole Star. and thence round to the bright group containing Vega on the opposite side of the pole. (p. 13)

It was by observation of the most southern of these stars (γ; also called Etamin) that Hooke and Bradley were led to the discovery of the aberration of light. The bright star Vega in the Harp is about 15° southeast of the Dragon's head. A star south of the head forms a diamond with 3 of its stars. This star lies in the left foot of Hercules, the remainder of the figure stretching to the south and west. The southern part of Cepheus lies in the Milky Way, the figure being on the east of the head of Draco (towards Cassiopeia.) 5 stars in Cepheus form a somewhat noticeable irregular X.

6. Camelopard. Dec. 70° N. Long. 80°. This constellation lies between Cassiopeia and the head of the Great Bear, and stretches southward to the

bright stars in Auriga. All of its stars are very faint.
South of its eastern point, between the head of the Great Bear and Auriga, is another faint constellation called the Lynx.

Constellations situated between the Northern Circumpolar and the Zodiacal.

1. Andromeda. (See Plate XII, Dec. 40° N. Long. 5°
One of the most conspicuous of the nebulae and the oldest known, appears in this constellation. It is visible to the naked eye and has often been mistaken for a comet. A line extending from the Pole-Star through the most western star but one in the W of Cassiopeia leads almost directly to it, at about half the distance towards the nearest star in the Great Square of Pegasus, which star also marks the head of Andromeda.[a] Two other bright stars winding around the W of Cassiopeia mark her belt and her foot.[b]

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[a] This star lies due south of the most western star in the W of Cassiopeia, both stars being in 0 longitude.
[b] These two stars with a third one on the north-east (about 10° north of Algol, the place of the latter being

Almach in the foot (See *Aries*, p. 77) is a handsome double star composed of a yellow and a blue sun. Struve also found one of these suns to be (itself) double.

2. *Pegasus, the Winged Horse.* (See Plate.)

Dec. 20° N. Long. 340°. Pegasus is represented flying head downwards, 3 bright stars curving around southwest of the Great Square in his body, forming his head and neck, and some small stars northwest of the Square, his fore feet. West of the head lie some faint stars in the head of *Equuleus*, the *Little Horse*, and west of these again a few degrees to the north, is a pretty little constellation named the *Dolphin*, the diamond part of which is also called "Job's Coffin." A line passing from the Pole Star through the most western star in the W of Cassiopeia leads beyond to the two left hand stars in the Great Square of Pegasus, the upper one of which also marks the head of Andromeda, as said above.

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shown in *Perseus*, p. 197 from the handle of another enormous dipper, the bowl of which is the Great Square of Pegasus. 3 stars running crosswise near the bowl represent the breast and shoulders of the figure.

3. Cygnus, the Swan. (See Plate VIII) Dec. 43° N. Long. 305°. The main part of Cygnus is shaped something like the half of a wheel. 5 stars in this part form the top of a cross, the foot of which is a star lying at some distance to the southwest. This foot star, which also marks the bill of the Swan, is a fine double composed of a golden yellow and a blue one. α Cygni (Deneb), the head star of the Cross, is the star that is coming most directly to our system. (See p. 155) The star next south (κ) of the east arm of the Cross is surrounded by a celebrated nebula, known as the Ring nebula. 61 Cygni, also a double, situated about one fifth way around the rim of the wheel from the east, is famous for having been the first star whose distance from the earth was revealed by parallax. (See p. 157) The Swan is situated in the fork of the dividing streams of the Milky Way, in the east of the Harp, which constellation, as we have seen, (p. 165) lies near the head of the Dragon. In 1876, a new star of the 3d magnitude continued visible for a few weeks in this constellation.

South of the Swan, between it and the Eagle, lie some faint stars forming Vulpecula, the Little Fox.

There is a celebrated nebula in this constellation.

4. Aquila, the Eagle. Dec. 2° N. Long. 292°. Aquila lies just southwest of the Little Dolphin, the Milky Way crossing its western part. It may be known by 3 of its principal stars forming a straight line, the middle one, Altair, being the brightest. A row of small stars north of this line form Sagitta, the Arrow. Between these and the Swan lies the Little Fox, already mentioned.

5. Lyra, the Harp. Dec. 37° N. Long. 280°. The 3 fine stars in the Eagle point northwest to the brilliant star Vega in the Harp, a constellation lying midway of Cassiopeia and the Great Dipper. Herschel has judged the diameter of Vega to be about 33 times that of our sun.* This constellation contains a roundish nebula (about half-way between the stars β and γ), which is considered to be one of the most curious and interesting objects in the heavens. The light from this nebula is supposed to be at least 20,000 years in reaching us, so that were it blotted from space

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*The distance of a star being known, as in the present case (see p. 173), its diameter is then estimated from its brightness, there being no disk to reckon by, as with the planets. (See p. 177)

now, we should continue to see it 20,000 years longer. East of Vega are two stars forming a small triangle with it: the most northern of these (ε) is a quadruple, in which one pair revolves around the other pair[a], while each pair shows one of its stars revolving around the other one. The star about 5° southeast of the triangle (β[b]) is a variable, going through its changes, which range from the 3d to the 5th magnitude, in about 13 days. The star selected by Struve for the measure of relative parallax[c] was the bright one of Lyra, i.e. Vega.

6. Corona Borealis, the Northern Crown. (See Plate V) Dec. 33° N. Long. 233°. A line leading from

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[a] The periods of the stars are often immense: thus the period of this pair is estimated to reach nearly a million years; the periods of the revolving stars in each pair 1000 and 2000 years respectively.

[b] This star is remarkable for having two maxima and two minima of unequal brilliancy. Newcomb.

[c] Its parallax, as measured from a very minute star near it: this is about .15" .2", showing Vega to be more than twice as far from us as the pair 61 Cygni, although it is nearly 100 times as bright as either of the two stars.

(See end of E., p. 11)

the Pole Star through the outermost star in the Little Dipper, and continued about three times as far from the pole as this star, passes just west of the Northern Crown. This constellation is principally composed of a pretty semi-circle of stars, all quite small excepting one of the 2nd magnitude, which is sometimes called the "Pearl of the Crown", but its proper name is Alphecca. (See Boötes, p. 18. See also "New Stars" p. 144)

7. Boötes, the Bear-Keeper. Dec. 30° N. Long. 217°

Boötes is marked by Arcturus*, a very bright, reddish star, easily found by continuing the curve formed by the Bear's tail, or handle of the Great Dipper. The Pearl of the Crown also forms the southeast extremity of a large Y of 6 stars, of which Arcturus is the bottom. The star at the fork, called Mirac (ε), is composed of a

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*This star moves through space three times as fast as the earth, but it takes it a century to appear to move the eighth part of the diameter of the moon.

"Mr. Stone has arrived at the conclusion that Arcturus sends us about as much heat as would be received from a 3 inch cube full of boiling water placed at a distance of 383 yards. Vega about the same."

Proctor.

yellow and a blue green sun. There are 4 others of the more remarkable doubles in this constellation.

8. Hercules. (See Plate 1). Dec. 30° N. Long. 258°. Hercules is a very large constellation, but contains no striking stars. It lies between the Crown and the Harp, and, as seen in the Plate, its two most southern stars point towards Vega. The few stars below the Crown at the right belong to another constellation, the Serpent.[a] Hercules somewhat resembles a giant lily with its cup open towards Vega. There are two double stars in Hercules of the colors yellow and emerald. It is towards a point in Hercules, about half-way between Vega and the N. Crown, that our solar system is at present travelling at the rate of about 5 miles a second. (See p. 57). Hercules contains a triple star (μ), in which two suns in revolution around each other also revolve around a 3d and much larger sun. Between its stars η and ζ is also found one of the most magnificent clusters in the northern hemisphere. In the Plate these stars are the two pointing north (to the top of the Plate), the 3d and 4th from the top on the right.

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[a] This constellation winds south, then east and southeast, where it lays above Scorpio, and then northeast up to the Eagle.

9. Ophiuchus, or Æsculapius. Dec. 5° S. Long. 255°
Ophiuchus lies between Hercules and Scorpio, and though a very large constellation contains only a few distinct stars. Two north of the tail of Scorpio lie in the left leg of the figure, and one east of a long triangle of 3 stars[a] about 20° north of these, marks the head. In 1604 an apparently new star was seen in Ophiuchus, and continued visible for more than a year.

10. Auriga, the Wagoner. Dec. 45° N. Long. 90°.
Auriga lies east of the Great Bear, forming the first bright group in this direction just beyond a faint region called the Lynx. (See Camelopard, p. 8.) It may readily be recognized by the bright star Capella[b] of the 1st magnitude, with its lesser companion, Menkalina, about 8° to the east of it. The star of the Bull's right horn (most northern) also marks the right foot of Auriga. The Milky Way

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[a] The most northern of these marks the head of Hercules.

[b] The top stars of the Great Dipper point nearly to Capella. Capella and Vega, both striking stars, as mentioned in the text, lie about 180° apart; with the Pole-Star nearly midway between them.

passes through the southwest part of Auriga.

11. Perseus. (See Plate VII) Dec. 45° N. Long. 3°. Perseus lies between Auriga and Cassiopeia (on the east of the latter) and may be known by a row of conspicuous stars extending along the Milky Way, which passes directly through this constellation. Algol, the famous variable (See p. 148) is the brightest star in the south of Perseus, about equally distant from the head of the Ram and the Pleiades, considerably to the north. A patch of light in Perseus, a little north of the eastern stars in the W of Cassiopeia, marks one of the fine stellar groups in our sky.[a]

Constellations South of the Zodiac that are visible in Northern and Middle Latitudes.

1. Cetus, the Whale. (See Plate VIII) Dec. 13° S.

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[a] "On examination with a small telescope one of the most beautiful groups of stars is in the constellation Perseus. It is seen to the best advantage with a low magnifying power between 25 and 50 times, and may easily be recognized by the naked eye as a little patch of light". Newcomb.

Long. 18°. Cetus commences just below Aries, and stretches southeast nearly to Aquarius, lying almost horizontal in our latitude. It contains the remarkable star Mira (3d star from the top in the Plate), which is generally invisible to the naked eye. (See p. 48.) This star, when seen, lies nearly in a line with Almach in Andromeda, and the head of the Ram (See p. 77), about 20° south of the latter. The two stars on the left of it, as seen in the Plate, are about equally distant from the head of the Ram and the Pleiades, which will assist to find its position. These two stars mark the head of the Whale.

2. Orion. (See Plate VII.) Dec. 3° N. Long. 78°. A line passing from the Pole-Star through Capella in Auriga leads down to Orion, Capella being half-way. Or, the Bull's horns being found, Orion lies just south of them. As seen in the Plate, its outline is very noticeable from the manner in which it forms a large parallelogram, while the constellation is also strongly marked by the diagonal line of bright stars across its centre, the upper one of which almost touches the equator. This line of stars has received various

names, as "Orion's belt," "bands of Orion" (in Job), "Jacob's staff" &c. Rigel in the left foot (the right star at the bottom of the Plate) is composed of a white and a blue sun. The two outside stars of the belt are also double. The vertical row below the belt, called the "sword" of the hunter, contains the nebula, which, more than all others, has occupied the attention of astronomers and excited the wonder of observers.[a] (Newcomb). This fine constellation, in connection with the neighboring groups, constitutes the richest part of the visible heavens. Five somewhat bright stars below Orion form the Hare, and four or five still lower down lie in the Dove, while a large region of indistinct stars on the east, extending to the Whale, comprises the constellation of Eridanus.

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[a] "It surrounds the middle of these three stars. A good eye will perceive that this star, instead of looking like a bright point as the other stars do, has an ill-defined, hazy appearance, due to the surrounding nebula." Newcomb.

See N. for quotation marks.

The same star is a multiple, composed of one principal and several subordinate suns, known as the "trapezium of Orion."

3. Canis Major, the Great Dog. Dec. 22° S. Long. 100°. The Great Dog lies just below Orion on the left, and is easily recognized by Sirius*, the brightest fixed star in the heavens. A bright triangle of stars on the southwest of Sirius also belongs to this constellation, making it a very brilliant one. Sirius is a double star, and remarkable both for its scintillation and its dazzling whiteness (See "The Color of the Stars" p. [illegible]). From its brilliancy and known distance (calculated to be more than a million radii of the earth's orbit) it is estimated to have a diameter 12 times that of our sun. The Milky Way lies on the east of the Great Dog.

For Canis Minor, the Little Dog, see "Gemini" (p. 176). Procyon, its chief star, lies midway between Sirius and the Twin Stars, Castor and Pollux.

A faint collection of stars lying partly in the Milky Way between the two Dogs, is called "Monoceros".

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*Sirius long showed an irregularity in its motion which indicated that a satellite was revolving around it, which satellite was at length accidentally discovered in 1862.

The belt of Orion directs upward to the Pleiades and downward to Sirius.

4. Argo Navis, the Ship. Dec. 55° S. Long. 120°. Only a few stars in the north of Argo, lying just below the Great Dog on the left, are visible in our latitude. This constellation contains the most extraordinary known variable in the heavens (η, see p. 148), and also Canopus, the second brightest star to Sirius, both of which lie below our horizon. The Milky Way passes through the Ship.

5. Centaurus, Dec. 48° S. Long. 195°. This constellation is below our horizon excepting a small triangle of stars in the head, lying southeast of the Crow (See Virgo, p. 179). The nearest star to our system (See p. 15) lies in the Centaur, east of the Southern Cross. Sir John Herschel says of the cluster around ω in this constellation: "This noble globular cluster is beyond all comparison the richest and largest object of the kind in the heavens. The stars are literally innumerable, and as their total light when received by the naked eye affects it hardly more than a star of the 4th or 5th magnitude, the minuteness of each star may be imagined." The same author describes another southern cluster (in Toucan, on the opposite side of the pole from the Centaur) as 'a most glorious globular cluster

the stars of the 13th magnitude immensely numerous and the centre of the cluster compressed to a blaze of light."

Southern Circumpolar Constellations

Of these, that of the Cross is described as prominent. Its 4 principal stars cover a space in the sky about the size of the quadrangle of the Little Dipper, at about twice the distance from the pole. The head and foot stars lie nearly in the same celestial meridian, and are therefore erect when passing the meridian of any place. It is known at what hour of the night in different seasons the Southern Cross is erect or inclined, and hence it serves as a time-piece to every nation that lies between the tropics or in the southern hemisphere.

The Cross lies between the Centaur and the Ship, the three constellations including mainly the brightest of the southern circumpolar stars. The splendor of this quarter is also heightened by the intense vividness of the Milky Way about the Cross (See 2, p 144), the whole offering a striking contrast to the opposite side of the pole, and especially to the

empty region about the pole itself.[a] If we add to this the great dissimilarity between the northern and the southern circumpolar groupings, we may form an idea of the impression which the latter produce upon the mind of the traveller as he sees them gradually rise above the horizon while he journeys southward. "The novelty and splendor" (says Sir John Herschel) "of fresh constellations gradually brought into view in the clear calm nights of tropical climates, in long voyages to the south, is dwelt upon by all who have enjoyed this spectacle, and never fails to impress itself on the recollection as among the most delightful and interesting of the associations connected with extensive travel." At the same time, nothing recalls more forcibly to the mind the immense distance by which the inhabitant of the southern temperate zone is separated from his native country.

[a] There is no southern polar star.

Chapter

Directions for Finding the Constellations.

In order to find when a star or a constellation culminates we must know its longitude, and in order to learn when it rises and sets we must know how many hours it continues above the horizon. This interval, except at the equator, depends upon the declination[a] of the body and the latitude of the observer. For example, let us find when Aries rises, culminates, and sets on Dec. 1. On this date the sun's longitude is 250° (See p. [illegible]; the longitude of Aries is 38°: Aries is therefore 148° (360 − 250 + 38) <u>east</u> of the sun, and culminates as many hours <u>after</u> the sun as 15 is contained times in 148, or about 10 P. M. In northern middle latitudes Aries continues 14 hours above the horizon, its declination being 20° N. On Dec. 1 it therefore rises 7 hours before 10 P. M. and sets 7 hours after 10 P. M.

Another example: When does Gemini, rise, culminate,

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[a] Declination corresponds to terrestrial latitude: reckon both this distance and longitude from the <u>centre</u> of a constellation.

The declination and longitude of the constellations, as has been seen, are given in the chapter treating of them; they are also given in star-maps.

and set on Aug. 20? The sun's longitude is 150° on Aug. 20; the longitude of Gemini 105°. Gemini is therefore 45° <u>west</u> of the sun and culminates 3 hours before noon. Gemini continues about 15 hours above our horizon, and therefore rises and sets 7½ hours before and after 9 A.M. on Aug. 20.

A constellation culminates at midnight whenever the sun is opposite to it in longitude, therefore 180° plus the longitude of a constellation will give the sun's longitude and hence the time of year when the constellation thus culminates: for instance, 180°+38°, the longitude of Aries, equals 218°, which is the sun's longitude on the 28th of Oct., and the time at which Aries culminates at midnight.

A constellation culminates two hours earlier for every month preceding its midnight culmination, and two hours later for every month following it: thus Aries culminates at 10 P.M. on Sept. 28, 2 A.M. on Nov. 28, and so on.

Stars situated on the equator[a] continue 12

[a] In our latitude the celestial equator rises from the eastern and western horizontal points to a point

hours above the horizon, whatever the latitude of the observer. In northern middle latitudes, stars 10°, 20°, 30° and 40° north of the equator continue respectively about 13, 14, 16 and 19 hours above the horizon, while stars having the same range of southern declination are in our sky the respective intervals of 10, 8½, 6½ and 3½ hours. Those stars or constellations whose distance from the pole does not exceed the latitude of a given place never set at such place, but describe their whole diurnal circle above the horizon. Correspondingly, stars ranging the same distance from the opposite pole never appear above the horizon of such place. (See p.

Stars or constellations situated on the equator rise in the east and set in the west, whatever the latitude of the observer. Stars having declination rise out of the east and set out of the west an amount proportioned to the latitude of the observer. In northern middle latitudes, stars situated 10°, 20°,

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about half-way to the zenith, while the course of the in the sky is constantly shifting, owing to its inclination to the direction of the earth's daily motion.

30°, and 40° north of the equator rise and set respectively about 13°, 23°, 35°, and 47° north of the east and west points. Again, situations 10°, 20°, 30°, and 40° south of the equator place the rising and setting points, in northern middle latitudes, respectively about 13°, 24°, 37°, and 52° south of the east and west points.

Constellations whose declination equals the latitude of a place, culminate overhead at the place. Constellations differing in declination culminate as many degrees north or south of the zenith as their declination is north or south of the given latitude.

Seeing that the zodiac contains 12 constellations, each of these is about a month advancing through a given portion of the sky. Having become familiar with one, and knowing the names of its successors, the observer can readily follow the list, as they come up in turn above the eastern horizon.

The sun begins to journey through the southern zodiacal constellations on Sept. 20, therefore at this date the northern zodiacal constellations commence their passage along our midnight sky, Pisces, Aries, &c. On Mar. 20 the case is reversed, Virgo, Libra, &c. now marking out the zodiac for us, and showing its southern range by their low

culmination. The zodiacal constellations, when on the meridian, may serve as guides to those having the same longitude, and which therefore now lie on the north and south of the former.

Owing to the earth's annual motion, combined with its diurnal, the constellations describe about 1° more than a circle during the 24 hours, so that every 3 months they occupy a position 90° distant from that which they occupied at the same hour of the night 3 months previously, still keeping their relative situation to each other. If the student will refer to Plate and revolve the book in the direction of the diurnal motion (from left to right), he will see the different positions which the Bears occupy in the sky during the 24 hours. The Pointers lie on the same meridian, as they appear in the Plate, so that their constellation is here shown in its lowest position, while the book turned upside down shows it in its highest position, when it is again on the meridian.[a] With the left side of the Plate

[a] When the sun's longitude is opposite that of the constellation, the former position occurs at noon and the latter at midnight, while the reverse takes place with the

down, he sees it on the east, as it appears early in Oct. at 8 o'clock P.M., and with the right side of the Plate down, on the west, as it appears 12 hours after, or at the same hour early in Apr., 6 hours of diurnal rotation and 3 months of annual revolution displacing the stars the same amount.

Again, if the student will refer to Plate and place the left side of the Plate down, he will see Orion as it rises at the equator, for with us the obliquity of the horizon to the equator cuts off the lower left-hand corner, the Plate being upright. Now revolving the book in a direction contrary to that mentioned in the case of Plate , for facing Orion at the south we stand, as it were, behind the dial, the varying position of the constellation regarding the horizon is shown, until it appears as setting, with the right side of the Plate[a] down. These two illustrations

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sun in the same longitude. As stated above, every month makes a difference of 2 hours in the times of these two culminations.

[a] All the Plates show the constellations as they appear when on the meridian, those which are lettered sidewise having their northern part at the left side of the leaf.

will convey an idea of the varied appearance which the constellations present in our sky from evening to morning, and at different times of the year. This variety is quite perplexing to the young observer, but he will be assisted in his search if he will bear in mind that the northern part of a constellation always lays towards the north star, and that a line from this star to the north of the figure will run beyond, through the figure, precisely as a meridian runs through it on maps, or a straight line runs downward through it as shown in Plates I, II, &c.

Constellations appear smaller high up than when near the horizon. (For their relative distances in the two positions see "The Moon in the Horizon" p.) This is because they are seen through a rarer atmosphere in the former position.

The student will observe that a star map is marked east on the left and west on the right. If he will hold the map over his head with the top of it towards the north, he will see that east and west on it then correspond with east and west on the ~~horizon~~ earth's surface. = p. 35 We are on the inside of the celestial sphere, and the outside of the earth, which difference of situation reverses the right and the left hands

the same as viewing a dial at the front of it and then behind, as mentioned in the case of Plate

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a "In the celestial sphere the points of the compass have of necessity a meaning which may seem different from that which we attribute to them on the earth. North always means towards the north pole; south, from it; west, in the direction of the diurnal motion; east, in the opposite direction." Newcomb.

STATE NORMAL SCHOOL,

AT

WEST NEWTON, MASS.

To Whom it may Concern:

THIS CERTIFIES

That Ellen E. Fitz.

of West Newton. –

has completed the term prescribed by the **BOARD OF EDUCATION** *for Pupils at this Institution.*

I believe that she possesses those qualifications, natural and acquired, which should ensure her success as a **TEACHER** *in the* **COMMON SCHOOLS** *of this State; and do cheerfully commend her to the favorable regard of such as would avail themselves of her services.*

Eben S. Stearns.

Principal.

West Newton –

July, 26. 1858.

Perhaps Tom sent our card to you, but I will risk troubling you with them a second time

Windsor N.S.
16th Nov. 1878.

My dear Miss Fitz,

Indeed it is too bad that I neglected answering your kind letter of last year, how it came about I cannot think, except it was that at first we were so hurried among the multiplicity of things that had to be ~~attended~~ seen to, that when time did come in which it might have been attended to it seemed like a ghost of the past. Not that you had passed from our recollection for from time to time our dear friend and her clever invention would be spoken of, and mother would say "Lizzie, write to Miss Fitz very soon." And I would answer

all in good faith "I will" and there 'twould drop, till next time.
What changes since I last saw you! Immediately after the fire our family for the first time separated, Mother went to Windsor taking Amelia with her, Tom remained in the City while Arthur and I dived deep into the country and spent nearly three months there. In Sept. I returned to St. John to take charge of a school. In a little while Tom and I had a house furnished for mother and the rest and on the 17th she returned and once more we were together; and from Sept. 1877 to Sept. 1878 seems like a dream, I never knew a happier year, nor one that passed so quickly. Now Tom is in business for himself and will succeed if any one can in these depressed

times) His expenses are light, and he is careful not to take on too heavy a stock, he is caution personified; so what more can be done except to trust to chance. As for myself you will smile when I inform you that I rejoice in the title of Mrs. J. F. Chandler, and am the happiest little body in all this pretty town of Windsor. You would like my husband he is handsome, clever, cheerful, and very much in love with your humble servant. We were married by Rev. G. A. W. Carey on the 24th of Sept. took a trip to P. E. I. and arrived home on the following Saturday. In summer time our garden is a perfect paradise, and the fruit and vegetables are delightful. But our content does not lie in the

possession of these things and we will be just as happy if they should ever be taken from us. Has anything satisfactory been done about your globe? Has it yet been introduced in the Boston schools? Write soon and give me a little information about yourself, and tell me what the last year has brought to you. In religious thought I have moved on a little; the Bible has fallen to pieces in my hands, and now I live free from all superstition and prejudice, I see good in every system and folly in all. I respect each person who lives aright and who treats each fellow traveller he meets with kindness. The evil and the good I find exist side by side, and the one is as indispensable as the other, indeed the evil may always be found wrapped up in the good, and the God who created all things meant it to be so. Excuse the haste in which

Jottings by the way.

No. 1.

THE REVIVAL AT ST. MARTINS.

A quarter of a century must make some change in a community; a number of houses must be built for an increasing population; an enlargement is seen in some respects; yet the aspects of Quaco are the same. The old meeting-house is the same; and accustomed to witness the educational progress in Nova Scotia, one looks in vain to see similar improvement here. New Brunswick requires a school law similar to her sister Province to develope the educational interests of the country. But here the writer met with a female teacher—a Governess in a private family—a native of the United States, who, in her leisure hours, had translated Virgil. What will the A. M.'s of Acadia say when I tell them that this teacher has translated all the Eclogues of Virgil, the Georgics, and nearly the whole of the Æneid, in literal and elegant English, equal to Dryden. I consider myself a judge of Latinity. Some I have found having a degree who could not read six lines of Hexameter verse without blundering. Her translations from French and German were very fine; her music beautiful, and her map-drawing superb. The lady who employs her has a treasure of knowledge in the person of her Governess. A growing desire for superior culture is perceptible in the place; elegant mansions are rising up; and the carriage and pair of splendid animals indicate the social status of the owner. The visitor looks around for the beautiful garden, the thorn hedges, and the rare flowers which may be found in the possession of wealth; but there may be more taste for the beautiful curves of a large ship, and the solidity of her well timbered sides, than for those adornments which, though they may gratify the æsthetic element of our nature, may not be so profitable or add much to the weight of the purse.

The kindness and hospitality of the people are well known; you meet with courtesy without intrusiveness, and hospitality without officious familiarity. Their appreciation of old Puritanic divinity is very perceptible; they constitute a material which may become one of the strongest Baptist interests in the Province. They require good schools; an Academy, or High School, is a desideratum for the place.

A few of the leading men talk of altering the old house of worship, and fixing it up in more modern style. A steeple would be an improvement. A good bell would remind the folk of the hour of worship, and arouse some absent-minded preacher to think of his apppointment. More anon. H.

Ellen E Fitz

Graduating Exercises of the Senior Class

—IN THE—

STATE NORMAL SCHOOL, AT WEST NEWTON,

TUESDAY, P. M. JULY 26, 1853.

I. HYMN,—by Miss L. P. Stone, Newburyport.

Oh glorious God! who on the earth dost spread,
More beauty than our souls can understand,
And with the solemn night above our head,
Hang'st orbs of light in full harmonious band!

Who mak'st the orient skies bloom with thy ray,
Who deckest purple West with Jasper bright!
Her gates gleam golden with the fading day,
And open gently to the starry night.

Thy riches on the hill-sides' various green,
Thy softened light in its ephemeral mist,
Thy glory's full bestowal round us seen,
The love it wakens filling every breast!

May thoughts Thou [illegible] stars of night!
May love Thou wakest be our [illegible]
From the celestial city show us light,
And bring us dawning of its glorious day.

II. REPORT,—by the Principal.

III. SONG,—by Miss M. J. Mitchel, Newry, Ireland.

See the gallant Oak is thriving,
Tho' each fruit and leaflet falls;
Tho' rude winter winds are striving
Through the forest's gothic halls.
Deep into the earth he fas'ens,
His still, firm, and strong old roots,
Every falling leaf but hastens,
Coming store of flowers and fruits.
Up to Heaven as fondly reaching,
The sure coming Sun to greet,
High his giant branches stretching,
Blessed with this assurance sweet;
That the glad bright spring appearing,
Richest wealth of green will bring,
And he looks up never fearing,
She will crown him forest king.

So will live our tree so goodly,
Tho' we now as leaves may go;
Tho' bleak winds sweep ne'er so rudely,
Her half-empty dim halls through,
In warm human hearts for ever,
Her old roots are firmly sunk,
Oh! then let's each endeavour,
To keep strong our parent trunk.

Summer, too, for her is bringing,
Leaves to clothe her boughs once more,
Gentle dews and sunlight flinging,
O'er her beauty as of yore.
Still may God's supremest blessing,
Now, as ever, be shed free;
Hope's bright sun and faith's refreshing
Kindly guard our old Oak Tree.

IV. POEM,—by Miss Louisa P. Stone, of Newburyport.

V. VALEDICTORY ADDRESS,—by Miss Jane Andrews, of Newburyport.

O'er us bends the heaven's azure,
At our feet the wild flower springs,
Round us whisper sweetest voices,
Like the sound of angel's wings.

Tell they of the heavenly kingdom,
Of the great all-Fathers' love,
Of His care for little children,
Who through all the earth-fields rove.

Bidding us with kindness gentle,
Win them from the ways of sin,
Leading them in paths of goodness,
Paths the Savior walked within.

Giving us a mission holy;
Thus the little hands to hold,
Thus to guide the footsteps wayward,
Lest they stray without the fold.

Let us, then, with hope aspiring,
Do the work to us that's given,
Ever looking upward, knowing,
Christ has said "of such is heaven."

VI. HYMN,—by Miss E. S. Nutting, Marblehead.

VII. PRESENTATION OF CERTIFICATES.

VIII. PARTING HYMN,—by Miss E. S. Nutting, Marblehead,
(sung by the Graduating Class.)

Father in Heaven, before whose throne,
Our hearts would lowly bow,
Grant us to say, "Thy will be done,"
Though sad and tearful now.

With strengthened heart we've sought to trace,
The path to duty on,
Dependant on thy bounteous grace,
To make the victory won.

Thou'st spared us, Father; and Thy love,
Has on our pathway smiled,
Bidding us look to Thee above,
And owning each Thy child.

Thus hand in hand we've journeyed still,
Thy blessing on our way;
But now we part; it is Thy will,
We may not longer stay.

We part; and when in sorrow's hour,
The weary heart grows sad,
When hope is gone; and dark skies lower,
This thought shall make us glad;

That we may still before Thee come,
And feel Thy presence bright,
Pointing the fearful to their home,
And making darkness light.

Then, Father, bless us as we bow,
Still keep our chosen band,
And may we all, made one, as now,
Be found at thy right hand.

IX. ADDRESSES,—by the Board of Education.

X. DOXOLOGY.

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To wit: **BE IT REMEMBERED,**

That on the 27th day of April anno domini 1876 Ellen E Fitz of the United States has deposited in this Office the title of a Book the title or description of which is in the following words, to wit:

Hand-Book of the Terrestrial Globe;

or,

Guide to Fitz's new Method of Mounting and operating Globes, designed for the use of Families, Schools, and Academies

By, Ellen E Fitz,

Boston:

Ginn Brothers

1876

the right whereof She claims as Author in conformity with the laws of the United States respecting Copyrights.

A R Spofford

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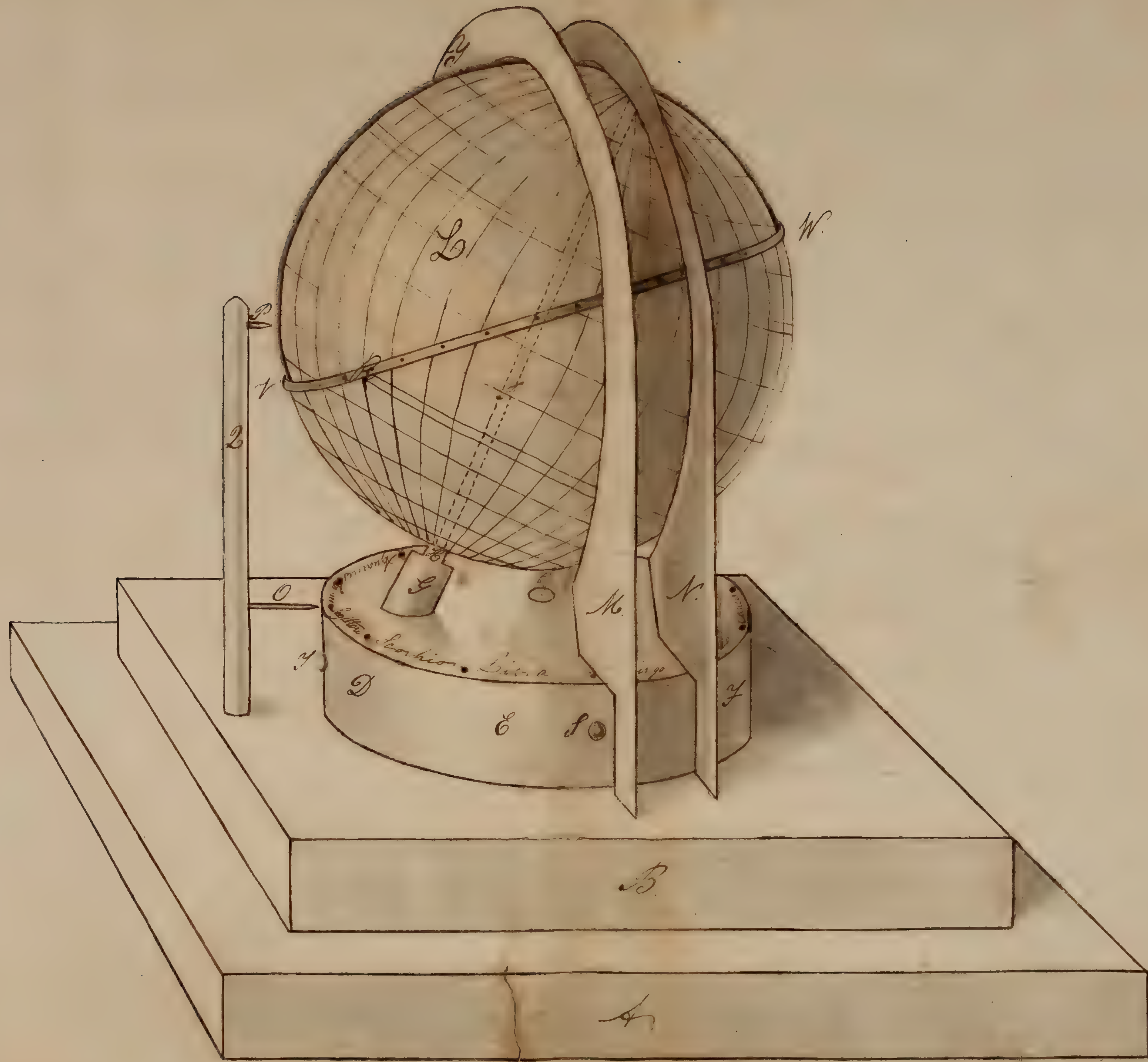
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UNITED STATES PATENT OFFICE.

ELLEN E. FITZ, OF ST. JOHN, NEW BRUNSWICK, CANADA.

MOUNTING AND ATTACHMENT FOR TERRESTRIAL GLOBES.

SPECIFICATION forming part of Reissued Letters Patent No. 9,557, dated February 8, 1881.

Original No. 158,581, dated January 12, 1875. Application for reissue filed May 29, 1879.

To all whom it may concern:

Be it known that I, ELLEN E. FITZ, of St. John, New Brunswick, have invented a Method of Mounting and Operating Globes, of which the following is a specification.

The purpose of my invention is to provide an instrument or apparatus for use in schools, families, &c., to illustrate and explain the manner in which the earth, in accordance with its diurnal and annual motion, presents its surface to the sun's rays, my especial object being to ascertain the various durations of day, night, and twilight throughout the year at any given terrestrial positions or localities, and also, in treating of day, to ascertain the points of the rising, setting, and culmination of the sun and the various courses the latter pursues in its relation to different horizons.

The drawings accompanying this specification represent, in Figure 1, a perspective view of an instrument or apparatus embodying my improvements, Fig. 2 being a vertical section of the same, taken through the supporting-post or axis of revolution of the globe.

In carrying out the objects I have in view I provide a flat tablet or base-plate, A, of suitable size and material, usually of wood, and upon the top of this tablet I add or create, for convenience of manufacture, a lesser plate or extension, B. Upon the plate B, I erect a perpendicular post, C, which constitutes an axis or point of revolution to a horizontal disk or cylinder, D, which is disposed upon the top of the plate B, and practically centrally thereof, the said disk turning freely upon its pivot C, and being preferably provided with knobs *a a*, which stud its periphery, by which its revolution may be facilitated. Upon the upper surface or plane of the disk B, and to one side of the center of the same, I erect a post or rod, E, which slopes inward toward and beyond the center of such disk at an angle of twenty-three and one-half degrees (or at such an angle that a prolongation of the pivot or axis of the disk shall intersect the center of the globe) with the plane of the disk, such rod constituting the axis about which the globe G revolves, and being formed with a shoulder, *b*, to maintain such globe at some altitude above the disk B, the diameter of the rod immediately outside of the globe being as small as is practicable, in order to obscure the south pole of the globe as little as possible.

H I in the accompanying drawings represent two arched standards, which span the globe, and are erected upon the plate B, with their feet upon opposite sides of the latter, and these standards approach the south pole of said globe upon each side as nearly as may be, and allow space for the passage of post E as it rotates past them. The standards H I serve to separate the two hemispheres which denote day and night upon the earth's surface, the former, H, representing the circle of illumination upon the earth's surface and the latter the circle which divides the section of the earth's surface within total night from that in twilight, the former phase being shown to the right of the standard I, and that in twilight between the two standards. As the standards H I cannot, owing to the passage of the post E, completely encircle the globe, the circle of illumination is necessarily incomplete or broken for a short distance upon either side of the south pole; but this defect is unimportant. As the globe is to be manipulated at certain times without the aid of these standards, I prefer that at such times they should be removed from close contact with said globe, and to this end I dispose them upon a frame, J, which slides horizontally upon the plate B, and by means of which they may be moved into action in the position shown in the drawings, or removed a short distance therefrom when not needed.

Upon the upper surface of the disk D, and immediately about its periphery, I inscribe a scale of divisions, which divides the said disk into twelve equal intervals, these divisions representing the imaginary plane of the ecliptic or orbit of the earth about the sun, the names of the signs of the ecliptic being added, as represented in the drawings. These twelve divisions are, in turn, each subdivided into ten equal divisions, which embrace or represent three days each, the first day of the month within each sign being indicated by an additional mark, which extends nearer the axis of the disk than the others, as the signs of the ecliptic do not reckon from the first day of the calendar month, but from the first day of the month upon which the equinoxes and

solstices occur. The degree of any sign in which the sun may be situated upon any given date may also be reckoned by means of the subdivisions of the scale upon the disk D. For instance, when the pointer *c* (to be hereinafter explained) points to the first mark within Scorpio the sun has entered the fourth degree of said sign, to the second mark of Scorpio the seventh degree, and so on, as the beginning of a sign, as before stated, takes date from the first instead of the twenty-first in reckoning degrees in lieu of days upon the scale.

In order to represent the passage of the sun through the signs of the ecliptic, or of the earth through the months of the year, I employ a pointer composed of a pointed rod or pin, *c*, which projects horizontally inward into close proximity to the disk from a vertical post, *d*, erected upon the plate B, and operates, in connection with the scale of divisions, upon the disk D, while, in order to represent the direction of the sun from the earth, or the situation of the sun with regard to the earth's surface—that is, the sun's vertical rays on the earth's surface—I employ a second pointed pin, *e*, likewise projecting inward from the top of the post *d* and coincident with the path of movement of the globe, or midway of the hemisphere of the latter, which denotes the illuminated half of the earth's surface, the pin or needle *e* also indicating the sun's vertical rays upon the earth's surface.

It will be observed that as the disk D revolves, the rod E (which serves as an axis to the globe) describes a path of the form of a cone, while the globe itself occupies a given position in space which, theoretically and literally, is not a correct representation of the annual motion of the earth, as the latter body is constantly moving forward in its orbit round the sun with its axis fixed in one direction; but this difference of motion between the true one of the earth and that of the globe intending to represent it is attendant with no difference in the movement of their surfaces—the former before the sun and the latter before an object representing such sun, as shown by the index-pointer *e*, which, as before stated, is coincident with the center of the globe G. My present instrument does practically exhibit the difference of motion in the surfaces of the earth before the sun, as I am enabled, by confining my apparatus to the purposes hereinbefore premised, to construct it with much greater simplicity than would be possible did I intend it as a planetarium—an instrument which mine is in no sense expected to supplant.

In order to obtain an adjustable device for readily defining and illustrating any required horizon, I employ a ring, K, of thin metal, which closely fits the greatest diameter of the globe G, and is divided upon its outer face into a scale of divisions of any desired number of degrees. While spanning this ring centrally thereof and at right angles to its plane I employ a semicircular band, L, also of thin metal, which is similarly provided with a graduated scale upon its outer surface, this semicircular band being intended to represent a semi-meridian at any point upon the globe with which a central perforation, *g*, of the said band may coincide. As the standards H I and the horizon-ring K are not to be brought into use at one and the same time, the latter should be removed and laid carefully to one side while the standards are in use, and when the ring is in use the standards, by means of the sliding frame J, are to be removed from immediate proximity to the globe. By this means I avoid injury to either the standards or ring, which might otherwise ensue on rotating the globe with the latter affixed to it. By means of the standards H I, which, as before stated, separate the two hemispheres representing day and night, we can illustrate the seasons, ascertain clock time, define twilight in its various phases, compute length of day and night, &c.

The diurnal course of the sun is ascertained by the ring K, as the passage of the pointer or needle *e* above it denotes the sun's diurnal course above the horizon of the given place, and by so adapting the band L to the globe that it corresponds with the meridian of this given place and its perforation or peep-hole *g* is coincident with such place the course of the the sun with respect to the horizon is obtained.

My present instrument, as before briefly stated, has two motions—one a revolution of the disk D about the pivot C, which is intended to represent the passage of the sun through the signs of the ecliptic, and therefore of the earth through the months of the year, and the second, a revolution of the globe G about the rod E, which is to represent the passage of the earth's surface through day, twilight, and night.

The half of the globe G nearest or adjacent to the pointer indicating the sun's vertical rays ~~or~~ with the index *e* denotes the hemisphere of the earth's surface which is in day, and the opposite half that which is in night.

When the globe is to be revolved into a given time of year it is to be moved bodily by and with the disk D, which latter is rotated upon its axis C. When the globe is to be revolved for the purpose of describing the daily course of the sun it is to be rotated upon its axis E, the disk D remaining stationary. It requires one diurnal revolution of the earth to complete a vertical illumination, to which allusion has previously been made in this specification, and whenever a circle upon the earth's surface is said thus to be illuminated vertically it should be borne in mind that but one position within this circle is illuminated at any one instant.

As an instance of the value and practicability of my system in this respect, revolve the disk D a number of times and it will be observed that the frigid zones continually pass to their full extent into one or the other of the hemispheres upon either side of the center of illumination, and a vertical sun (which in my

instrument is represented by the needle *e*) continually travels to and fro of the torrid zone, each movement necessitating one-half a revolution of the disk to complete it, or occupying six months of time. Thus the operator or student cannot fail to see that the five zones are natural divisions of the earth's surface, and not the artificial and arbitrary ones of the geographer, and he is enabled to readily distinguish the prevailing climates of such earth's surface. When it is not convenient to count the intervals upon a southern parallel they may be counted upon the corresponding northern parallel upon the opposite side of the circle of illumination, day upon the latter being of the same length as night upon the former, and vice versa. As the axis or rod E upon which the globe rests and rotates occupies a space of a few degrees about the south pole, the horizon-ring K cannot, under the construction shown in the accompanying drawings, be adjusted to represent the horizon of any situation upon the equator, or upon any parallel to either side of it, within the distance occupied by the rod E; but the horizon of any situation upon the equator may be represented by the meridian that is ninety degrees distant, while there will be but a slight variation in the course of the sun in the zone comprised within a few degrees upon either side of the equator. This objection, however, may be remedied, wholly or in part, by creating a notch in the ring K to receive the base of the rod E and permit the edge of the ring to coincide with the center of the globe.

For the full details of the working of my system reference must, of course, be had to the manual which I have prepared to accompany it, as it would manifestly be too prolix and unnecessary to make part of this specification. It may, however, be well, in this connection, to instance several examples of such working. For instance, see the following problem and its solution: Required to trace the course of the sun at Spitzbergen upon the 21st day of June, it being known that upon the 21st day of June the sun describes its whole diurnal course above the horizon at Spitzbergen, ascending from its lowest position, or twelve degrees above the northern point of the horizon, to thirty-five degrees above the southern point thereof, and again descending to its lowest position. Having adjusted the horizon-ring hereinbefore named to the situation of Spitzbergen, which is done by adapting the peep-hole *g* to the locality of said place, with the band L in the direction of the meridian of said place, and brought the globe into position for June 21, I ascertain, by rotating the said globe through one revolution upon its axis, that the sun describes its whole diurnal course above the represented horizon upon the given date, and therefore I start with the pointer opposite the band L, upon the side which describes the shortest distance to the ring, this distance being twelve degrees, and denoting the nearest approach of the sun to the horizon of Spitzbergen during the twenty-four hours of June 21. The globe being now rotated toward the left, the pointer gradually ascends to thirty-five degrees upon the semi-meridian of Spitzbergen, and then again descends to its lowest position, thereby giving the required course of the sun to be performed in a similar manner.

Again, upon the subject of twilight, I give the following brief example, and would preface it by the remark that, for the sake of convenience in the practice upon the globe when considering this subject of twilight, I prefer to call the lesser standard, I, the "twilight-circle." Required to ascertain the beginning, duration, and ending of twilight at Stockholm upon June 21, it being known that parallels have a twilight continuing through the night when their illuminated arc is contained wholly within the section of twilight. I first revolve the globe into position for June 21, as before stated, and then backward in the year until the parallel of Stockholm has its point most remote from the sun within the twilight-circle, at which time the index *c* is opposite April 26. I now revolve the globe forward in the year until the parallel of Stockholm again rests its point most remote from the sun within the twilight-circle, when I find the index opposite August 24. A season of twilight continuing through the night therefore begins at Stockholm on the 26th day of April and terminates on the 24th day of August, or continues during an entire period of four months.

To carry any given place forward in the day the globe G should be rotated from left to right, and to pass the signs on disk D forward said disk must be rotated from the left to the right also.

I claim—

1. In combination with a terrestrial globe, a fixed point in proximity to said globe, representing the sun, and a horizon-ring movable upon said globe, substantially as set forth.

2. The combination of a terrestrial globe having motions illustrating diurnal and annual rotation with a twilight-circle independent of the horizon and capable at all times of illustrating twilight without abnormal movement of said globe.

3. The combination of a terrestrial globe rotating on a suitably-inclined axis with a rotating disk, graduated as described, which carries said axis, arched standards representing the lines of light and of darkness, and a pointer which points to the graduations on the disk, for the purpose set forth.

4. A terrestrial globe illustrating both the diurnal and annual motions of the earth, in combination with a fixed sun-point, said globe being provided with a removable horizon-ring and twilight-circle, substantially as set forth.

ELLEN E. FITZ.

Witnesses:

F. CURTIS,

H. E. LODGE.

[illegible]

The United States of America.

No. [illegible]

To all to whom these presents shall come:

Whereas Ellen E. Fitz, of [illegible]
[illegible] Canada
ha[illegible] presented to the Commissioner of Patents a petition praying for the [illegible] of **Letters Patent** for an alleged new and useful improvement in
[illegible]
[illegible] issued to her, dated January 12 1875; which letters having been surrendered, the same have been cancelled, and new letters ordered to issue to her on an amended specification
a description of which invention is contained in the Specification of which a copy is hereunto annexed and made a part hereof, and ha[illegible] complied with the various requirements of Law in such cases made and provided; and

Whereas upon due examination made the said Claimant [illegible] adjudged to be justly entitled to a Patent under the Law.

Now therefore these **Letters Patent** are to grant unto the said

Ellen E. Fitz, her heirs or assigns for the term of seventeen years from the twelfth day of January one thousand eight hundred and seventy five the exclusive right to make, use and vend the said invention throughout the United States and the Territories thereof.

In testimony whereof I have hereunto set my hand and caused the seal of the **Patent Office** to be affixed at the City of Washington this eighth day of [illegible] in the year of our Lord one thousand eight hundred and seventy [illegible] and of the Independence of the United States of America the one hundred and fifth.

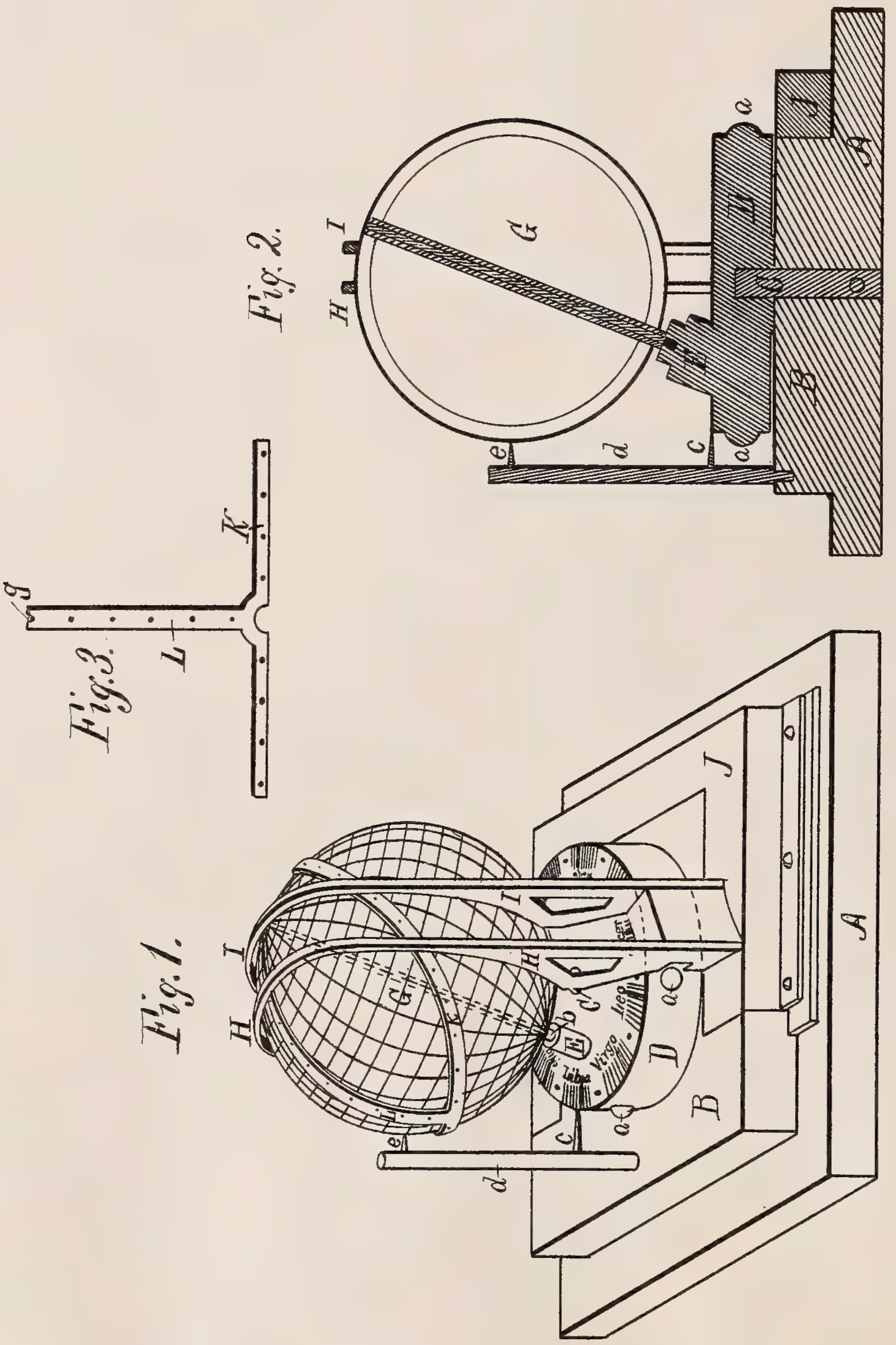
[illegible] Secretary of the Interior.

Countersigned [illegible] Commissioner of Patents.

E. E. FITZ.

Mounting and Attachment for Terrestrial Globes.

No. 9,557. Reissued Feb. 8, 1881.



Witnesses.
Edward F. H. Rouleau
H. E. Lodge

Inventor.
E. E. Fitz.
F. Curtis. Atty.

N. PETERS, PHOTO-LITHOGRAPHER, WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

ELLEN E. FITZ, OF ST. JOHN, NEW BRUNSWICK, CANADA.

MOUNTING AND ATTACHMENT FOR TERRESTRIAL GLOBES.

SPECIFICATION forming part of Reissued Letters Patent No. 9,557, dated February 8, 1881.

Original No. 158,581, dated January 12, 1875. Application for reissue filed May 29, 1879.

To all whom it may concern:

Be it known that I, ELLEN E. FITZ, of St. John, New Brunswick, have invented a Method of Mounting and Operating Globes, of which the following is a specification.

The purpose of my invention is to provide an instrument or apparatus for use in schools, families, &c., to illustrate and explain the manner in which the earth, in accordance with its diurnal and annual motion, presents its surface to the sun's rays, my especial object being to ascertain the various durations of day, night, and twilight throughout the year at any given terrestrial positions or localities, and also, in treating of day, to ascertain the points of the rising, setting, and culmination of the sun and the various courses the latter pursues in its relation to different horizons.

The drawings accompanying this specification represent, in Figure 1, a perspective view of an instrument or apparatus embodying my improvements, Fig. 2 being a vertical section of the same, taken through the supporting-post or axis of revolution of the globe.

In carrying out the objects I have in view I provide a flat tablet or base-plate, A, of suitable size and material, usually of wood, and upon the top of this tablet I add or create, for convenience of manufacture, a lesser plate or extension, B. Upon the plate B, I erect a perpendicular post, C, which constitutes an axis or point of revolution to a horizontal disk or cylinder, D, which is disposed upon the top of the plate B, and practically centrally thereof, the said disk turning freely upon its pivot C, and being preferably provided with knobs *a a*, which stud its periphery, by which its revolution may be facilitated. Upon the upper surface or plane of the disk B, and to one side of the center of the same, I erect a post or rod, E, which slopes inward toward and beyond the center of such disk at an angle of twenty-three and one-half degrees (or at such an angle that a prolongation of the pivot or axis of the disk shall intersect the center of the globe) with the plane of the disk, such rod constituting the axis about which the globe G revolves, and being formed with a shoulder, *b*, to maintain such globe at some altitude above the disk B, the diameter of the rod immediately outside of the globe being as small as is practicable, in order to obscure the south pole of the globe as little as possible.

H I in the accompanying drawings represent two arched standards, which span the globe, and are erected upon the plate B, with their feet upon opposite sides of the latter, and these standards approach the south pole of said globe upon each side as nearly as may be, and allow space for the passage of post E as it rotates past them. The standards H I serve to separate the two hemispheres which denote day and night upon the earth's surface, the former, H, representing the circle of illumination upon the earth's surface and the latter the circle which divides the section of the earth's surface within total night from that in twilight, the former phase being shown to the right of the standard I, and that in twilight between the two standards. As the standards H I cannot, owing to the passage of the post E, completely encircle the globe, the circle of illumination is necessarily incomplete or broken for a short distance upon either side of the south pole; but this defect is unimportant. As the globe is to be manipulated at certain times without the aid of these standards, I prefer that at such times they should be removed from close contact with said globe, and to this end I dispose them upon a frame, J, which slides horizontally upon the plate B, and by means of which they may be moved into action in the position shown in the drawings, or removed a short distance therefrom when not needed.

Upon the upper surface of the disk D, and immediately about its periphery, I inscribe a scale of divisions, which divides the said disk into twelve equal intervals, these divisions representing the imaginary plane of the ecliptic or orbit of the earth about the sun, the names of the signs of the ecliptic being added, as represented in the drawings. These twelve divisions are, in turn, each subdivided into ten equal divisions, which embrace or represent three days each, the first day of the month within each sign being indicated by an additional mark, which extends nearer the axis of the disk than the others, as the signs of the ecliptic do not reckon from the first day of the calendar month, but from the first day of the month upon which the equinoxes and

instrument is represented by the needle *e*) continually travels to and fro of the torrid zone, each movement necessitating one-half a revolution of the disk to complete it, or occupying six months of time. Thus the operator or student cannot fail to see that the five zones are natural divisions of the earth's surface, and not the artificial and arbitrary ones of the geographer, and he is enabled to readily distinguish the prevailing climates of such earth's surface. When it is not convenient to count the intervals upon a southern parallel they may be counted upon the corresponding northern parallel upon the opposite side of the circle of illumination, day upon the latter being of the same length as night upon the former, and vice versa. As the axis or rod E upon which the globe rests and rotates occupies a space of a few degrees about the south pole, the horizon-ring K cannot, under the construction shown in the accompanying drawings, be adjusted to represent the horizon of any situation upon the equator, or upon any parallel to either side of it, within the distance occupied by the rod E; but the horizon of any situation upon the equator may be represented by the meridian that is ninety degrees distant, while there will be but a slight variation in the course of the sun in the zone comprised within a few degrees upon either side of the equator. This objection, however, may be remedied, wholly or in part, by creating a notch in the ring K to receive the base of the rod E and permit the edge of the ring to coincide with the center of the globe.

For the full details of the working of my system reference must, of course, be had to the manual which I have prepared to accompany it, as it would manifestly be too prolix and unnecessary to make part of this specification. It may, however, be well, in this connection, to instance several examples of such working. For instance, see the following problem and its solution: Required to trace the course of the sun at Spitzbergen upon the 21st day of June, it being known that upon the 21st day of June the sun describes its whole diurnal course above the horizon at Spitzbergen, ascending from its lowest position, or twelve degrees above the northern point of the horizon, to thirty-five degrees above the southern point thereof, and again descending to its lowest position. Having adjusted the horizon-ring hereinbefore named to the situation of Spitzbergen, which is done by adapting the peephole *g* to the locality of said place, with the band L in the direction of the meridian of said place, and brought the globe into position for June 21, I ascertain, by rotating the said globe through one revolution upon its axis, that the sun describes its whole diurnal course above the represented horizon upon the given date, and therefore I start with the pointer opposite the band L, upon the side which describes the shortest distance to the ring, this distance being twelve degrees, and denoting the nearest approach of the sun to the horizon of Spitzbergen during the twenty-four hours of June 21. The globe being now rotated toward the left, the pointer gradually ascends to thirty-five degrees upon the semi-meridian of Spitzbergen, and then again descends to its lowest position, thereby giving the required course of the sun to be performed in a similar manner.

Again, upon the subject of twilight, I give the following brief example, and would preface it by the remark that, for the sake of convenience in the practice upon the globe when considering this subject of twilight, I prefer to call the lesser standard, I, the "twilight-circle." Required to ascertain the beginning, duration, and ending of twilight at Stockholm upon June 21, it being known that parallels have a twilight continuing through the night when their illuminated arc is contained wholly within the section of twilight. I first revolve the globe into position for June 21, as before stated, and then backward in the year until the parallel of Stockholm has its point most remote from the sun within the twilight-circle, at which time the index *c* is opposite April 26. I now revolve the globe forward in the year until the parallel of Stockholm again rests its point most remote from the sun within the twilight-circle, when I find the index opposite August 24. A season of twilight continuing through the night therefore begins at Stockholm on the 26th day of April and terminates on the 24th day of August, or continues during an entire period of four months.

To carry any given place forward in the day the globe G should be rotated from left to right, and to pass the signs on disk D forward said disk must be rotated from the left to the right also.

I claim—

1. In combination with a terrestrial globe, a fixed point in proximity to said globe, representing the sun, and a horizon-ring movable upon said globe, substantially as set forth.

2. The combination of a terrestrial globe having motions illustrating diurnal and annual rotation with a twilight-circle independent of the horizon and capable at all times of illustrating twilight without abnormal movement of said globe.

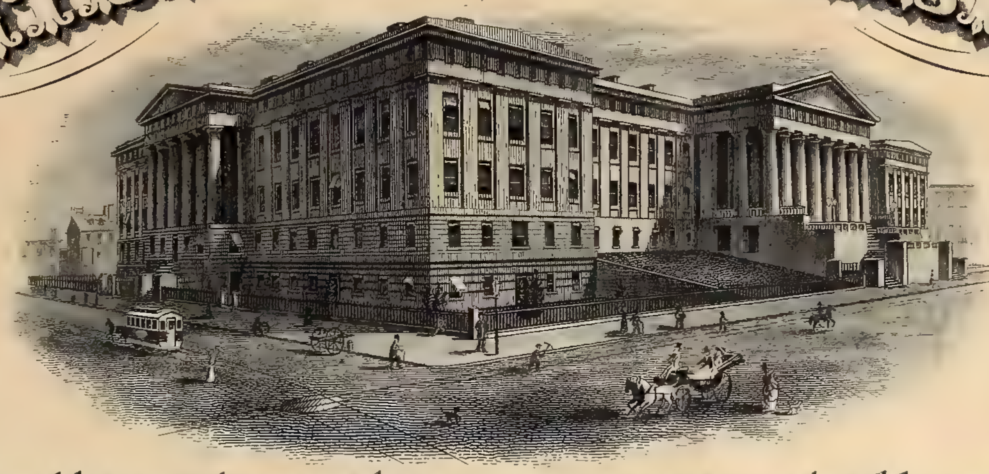
3. The combination of a terrestrial globe rotating on a suitably-inclined axis with a rotating disk, graduated as described, which carries said axis, arched standards representing the lines of light and of darkness, and a pointer which points to the graduations on the disk, for the purpose set forth.

4. A terrestrial globe illustrating both the diurnal and annual motions of the earth, in combination with a fixed sun-point, said globe being provided with a removable horizon-ring and twilight-circle, substantially as set forth.

ELLEN E. FITZ.

Witnesses:
F. CURTIS,
H. E. LODGE.

THE UNITED STATES OF AMERICA.



No. 263866.

To all to whom these presents shall come:

Whereas Ellen E. Fitz, of Somerville, Massachusetts, has presented to the Commissioner of Patents a petition praying for the grant of **Letters Patent** for an alleged new and useful improvement in

Globes,

a description of which invention is contained in the Specification of which a copy is hereunto annexed and made a part hereof, and has complied with the various requirements of Law in such cases made and provided; and

Whereas upon due examination made the said Claimant is adjudged to be justly entitled to a Patent under the Law.

Now therefore these **Letters Patent** are to grant unto the said Ellen E. Fitz, her heirs or assigns for the term of seventeen years from the fifth day of September one thousand eight hundred and eighty-two the exclusive right to make, use and vend the said invention throughout the United States and the Territories thereof.

In testimony whereof I have hereunto set my hand and caused the seal of the **Patent Office** to be affixed at the City of Washington this fifth day of September in the year of our Lord one thousand eight hundred and eighty-two and of the Independence of the United States of America the one hundred and seventh.

[illegible]
Secretary of the Interior.

Countersigned: [illegible]
Commissioner of Patents.

(No Model.)

E. E. FITZ.

GLOBE.

No. 263,886. Patented Sept. 5, 1882.

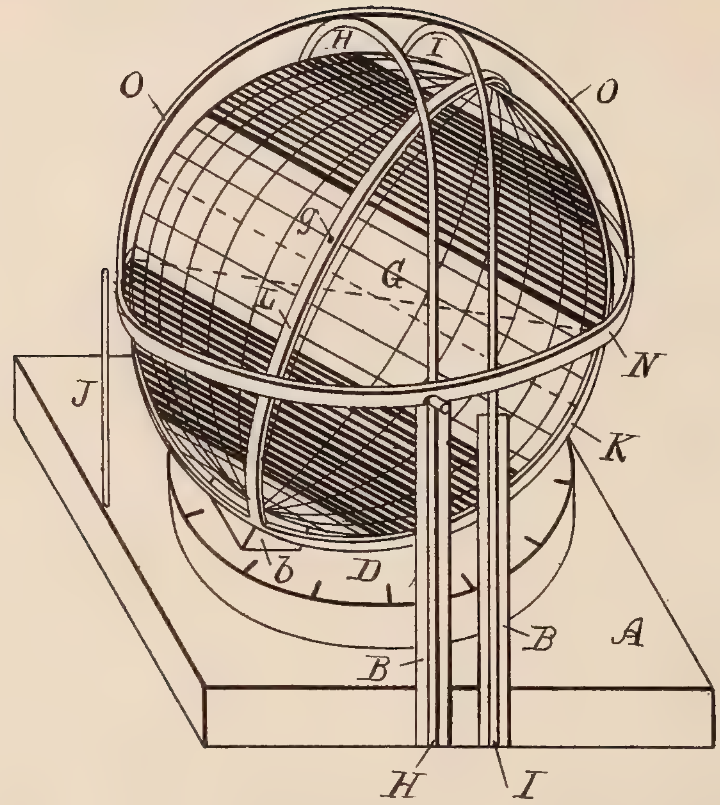


Fig. 1.

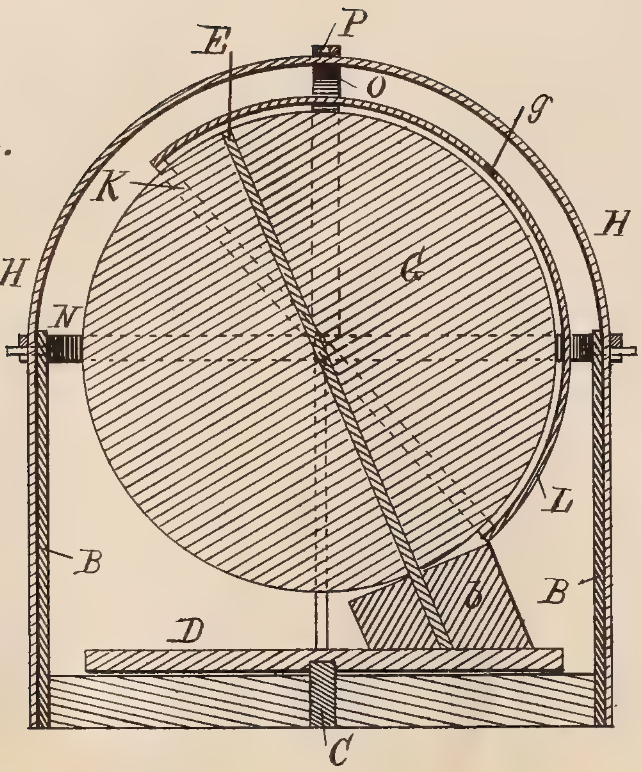


Fig. 2.

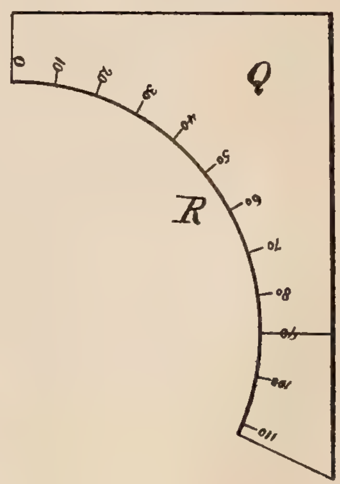


Fig. 3.

Witnesses.
H. C. Lodge
Wm. T. Andrews

Inventor.
Ellen E. Fitz.
F. Curtis. Atty.

N. PETERS. Photo-Lithographer, Washington, D. C.

UNITED STATES PATENT OFFICE.

ELLEN E. FITZ, OF SOMERVILLE, MASSACHUSETTS.

GLOBE.

SPECIFICATION forming part of Letters Patent No. 263,886, dated September 5, 1882.

Application filed November 5, 1881. (No model.)

To all whom it may concern:

Be it known that I, ELLEN E. FITZ, a citizen of the United States, residing at Somerville, in the county of Middlesex and State of Massachusetts, have invented certain new and useful Improvements in Globes; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same, reference being had to the accompanying drawings, and to letters or figures of reference marked thereon, which form a part of this specification.

My present improvements are based upon a class of globes shown and described in Letters Patent of the United States issued to myself on the 12th day of January, 1875, and reissued on the 8th day of February, 1881. The primary purpose of my globe as above patented is to illustrate and explain the manner in which the earth, in accordance with its diurnal and annual motions, presents its surface to the sun's rays, especially to ascertain the various durations of day, night, and twilight throughout the year at any given terrestial locality, and also to ascertain the points of rising, setting, and culmination of the sun and the course it pursues in its relation to different latitudes. In my present globe I propose, in addition to the above, to illustrate the aspects of the constellations at varying times of the year, together with the shifting position of the stars above any given horizon, thus ascertaining their amplitude, azimuth, &c. In this globe I retain from my patented globe the sun-point, the movable horizon-ring, the smaller arched standard or twilight-circle independent of the horizon, together with the larger arched standard representing the dividing-line between light and darkness, and the disk placed below and rotating with the globe, and having inscribed upon its upper surface the twelve months of the year with minor subdivisions.

My present improvements consist, first, in a globe provided with an outer and inner horizon-ring and their respective semicircular bands, one ring and its band being adapted to give terrestial indications, while the other ring and band give celestial indications, both being capable of use at the same time; secondly, of a globe provided with an arched standard, in combination with an outer horizon-ring, which oscillates on studs attached to the supports of said standard; thirdly, of a globe or ball divided on its surface into contrasting belts, in combination with an inner horizon-ring and an outer horizon-ring, all substantially as hereinafter set forth.

The drawings accompanying this specification represent in Figure 1 a perspective view of a globe embodying my present improvements, while Fig. 2 is a vertical cross-section through the day-circle, and Fig. 3 is a plan of the quadrant-plate.

Reference being had to the above-named drawings, it will be seen that A represents a flat tablet of proper material—usually wood—upon the top of which I erect centrally an upright post, C, which constitutes an axis of revolution for a horizontal disk, D, which is disposed upon such tablet A, and is capable of turning freely about such post. Upon the top of the rotary disk D, and to one side of its center, I erect a second post or rod, E, which slopes inward toward and beyond the center of said disk at an angle of twenty-three and one-half degrees with such top, such post constituting the support and axis of revolution of the ball G, and being formed preferably with a shoulder, *b*, upon which the ball rests and by which it is raised somewhat above the disk.

H I in the accompanying drawings represent two parallel arched standards, which span the ball G, the feet of which are erected upon opposite sides of such ball and upon the top of the tablet A. These standards H I serve to separate the two hemispheres which denote day and night upon the earth's surface, the former, H, representing the circle of illumination or day-circle and the latter the circle which divides the section of the earth's surface within total night from that in twilight, the former phrase, total night, being shown to the right of the standard I, and that in twilight between the two standards. As the standards H I cannot, owing to the passage of the post E, completely encircle the globe, the

(shown in the drawings at g) over the latitude of the given place, with its meridian L extending north and south, or in the direction of a meridian of the ball.

When the inner horizon-ring is used to locate any given star, which is done by placing its peep-hole over the position of the star as found upon a map of the heavens, it is unimportant what direction the meridian of such ring takes; but instead of using the ring for this purpose a few important stars may be located on the surface of the ball G by means of figures or other characters, the key to which may be furnished in a manual accompanying the apparatus.

The operator being provided with a map of the heavens and the earth, the positions of stars, cities, &c., are easily located on the ball G by means of their latitude and longitude.

To illustrate the manner of operating with my present apparatus, I append a few problems.

First. To show the course of the sun at Boston on June 20, bring June 20 on the revolving disk below the ball to the sun-wire. Find the latitude of Boston on atlas-map and adjust the inner horizon to this latitude on the ball. Bring the eastern edge of inner horizon to the top of sun-wire, or point representing the sun, for sunrise. Revolve the globe eastward till the western edge of horizon is brought to sun-point for sunset. Noon was shown when the point was opposite the meridian of the ring.

Second. To illustrate the change of the seasons, bring March 20 on revolving disk to sun-wire for beginning of spring. Observe top of said wire opposite the equator of ball, midway of torrid zone, the position of the sun at the vernal equinox. Revolve disk three months forward in the year, and observe sun-point crossing the northern half of the torrid zone and resting at the Tropic of Cancer on June 20, the beginning of summer and time of the summer solstice. Revolve disk forward three months for each succeeding season, and observe the corresponding passages of sun-point.

Third. To find the right ascension and declination of a star. Find position of star on atlas-map of the heavens and place peep-hole of inner horizon over this position on the ball. Revolve ball on axis to bring peep-hole to meridian of outer horizon. To this meridian apply the quadrant with the division marked O over the equinoctial of ball, and the degree of quadrant over the inner peep-hole will be the required declination. The number of degrees on equinoctial between the quadrant or outer meridian and first point of Aries will be the required right ascension.

Fourth. To find the amplitude of any star, its oblique ascension and descension, and its diurnal arc for any given day: Adjust the peep-hole of inner horizon over the position of star as found on atlas-map. Adjust outer horizon to latitude of place. Revolve globe on axis to bring inner peep-hole to eastern edge of outer horizon, and its distance from the east point of this horizon (measured by the quadrant) is the rising amplitude of the star, its oblique ascension the number of degrees between the east point of the horizon and the first point of Aries. Revolve globe on axis to carry inner peep-hole to the western edge of outer horizon for the star's diurnal arc. The distance of peep-hole in this position from the west point of said horizon is the setting amplitude of the star, and its oblique descension the number of degrees between the west point and the first point of Aries.

Fifth. The day being given, to find at what hour a given star comes to the meridian adjust inner peep-hole to position of star, bring sun's place in the ecliptic to outer meridian, turn globe westward till inner peep-hole comes to outer meridian, and the hours passed in turning (intervals of longitude) will be the time from noon when the star culminates or comes to the meridian.

The contrast of the zones is indicated in the drawings by belts alternately blank and provided with shade-lines. Of course on the globe itself the same result may be attained by contrasted colors.

I claim—

1. A globe provided with an outer and an inner horizon-ring and their semicircular bands, one ring and its band being adapted to give terrestrial indications, while the other ring and band give celestial indications, both being capable of use at the same time.

2. The combination, with a globe, of arched standard H and outer horizon-ring, N, which oscillates on studs attached to the supports of said standard.

3. A globe or ball divided on its surface into contrasting belts, in combination with an inner horizon-ring and an outer horizon-ring, substantially as set forth.

In testimony whereof I affix my signature in presence of two witnesses.

ELLEN E. FITZ.

Witnesses:
CHARLES BROTHERS,
F. CURTIS.

Observatory Vassar College Obs. Vassar College
June 4 1885

To

Ellen E. Fitz

My dear Miss Fitz,

Yours is rec'd. I am sorry to say that my knowledge about the moon, is derived wholly from books. The study of a satellites motion, is always difficult, on account of the combination of sun, planet and moon. The Observatory at Greenwich was founded wholly for the object of investigating the motions of the moon.

I am afraid that I can do little for you. I consider it my duty to rest in the summer

and to do little except copying and routine work. I have never made the Moon a specialty

I would suggest to you to make a model of moon, sun & Earth with the inclinations and study the complex relations by that method. But the authorities that you quote are good, and they can scarcely mislead you.

I shall keep your letter by me, and if anything occurs to me, that would help you I will write again as yet, I have simply looked it over.

I rejoice to know that you are studying so persistently — it is a good indication of the healthy movement of the age, when women give themselves to such solid work.

Yours sincerely
Maria Mitchell

Copy.

[Unless all parties interested assent to the account, they must be cited.]

The first and final Account of Solomon B. Stebbins,
Executor of the will of Ellen E. Fitz,
late of Watertown, in the County of Middlesex, deceased:

Said Accountant charges himself with the several amounts received as stated in Schedule A herewith exhibited, ... $ 1238.86

And asks to be allowed for sundry payments and charges as stated in Schedule B herewith exhibited, ... $ 1238.86

Balance, ... $ ———

Exec.

The undersigned being all parties interested, having examined the foregoing account, request that the same may be allowed without further notice.

COMMONWEALTH OF MASSACHUSETTS.

MIDDLESEX, ss. *At a Probate Court held at Cambridge* *in said County,*

on the *day of* *A.D. 188* ,

The foregoing account having been presented for allowance, and all persons interested having been duly notified to appear and show cause, if any they have, why the same should not be allowed,

and no objection being made thereto, and the same having been verified by the oath of the accountant and examined and considered by the Court,

IT IS DECREED that the same be allowed and recorded.

Judge of Probate Court.

SCHEDULE A.

	DOLLARS.	CENTS.
Amount of personal estate according to inventory, ...	1212	86
Balance of former account, ...		
Amount received from gain on sale of personal estate over appraised value, and from other property as follows:—		
Sale of copyright of Handbook of globe.	1	00
Sale of copyright of music.	25	00
	1238	86

Inventory
referred to above.

Cash on deposit in Suffolk Savings Bank,	799	70	
" " " " Provident Inst. for Savings.	132	16	
" " hand	30	00	
Gold watch and chain	25	00	
Piano	50	00	
Clothing	25	00	
Books.	25	00	
Furniture	25	00	
Globe patents.	100	00	
Ms. on astronomy.	1	00	1212.86

[This Schedule should be divided into classes; 1st, *debts of deceased;* 2d, *funeral expenses and expenses of last sickness;* 3d, *charges of administration.*]

SCHEDULE B.

		DOLLARS.	CENTS.
	Amount paid out and charges as follows:		
1886. Nov.	1st class. None.		
	2nd class.		
	Cash paid Alex. Gregg, undertaker.	61	50
	" " C. F. Fitz, for funeral expenses incurred at burial in Candia, N. H.	35	25
	" " M. Fitzgerald for headstone for grave.	65	00
	" " H. H. Cobb, M. D., for medical services from May 7 to Oct. 11, 1886.	62	00
	3rd class.		
	Cash paid Boston Transcript, adv. Probate notice.	5	00
	" " fees for appraisal of personal estate.	3	00
	" " Joseph H. Tyler, Register of Probate, for certificates.	4	50
	" " U. S. Commissioner of Patents, for recording transfer of patents.	2	00
	" " Librarian of Congress, for recording transfer of 2 copyrights.	2	00
	" " F. W. Rogers, Attorney, for attendance at Probate Court and Probate Office, East Cambridge; preparing papers; and expenses.	25	48
	" " S. B. Stebbins, Executor, services and expenses.	20	00
	" " Chas. F. Fitz, 1/2 net balance of estate.	476	5[illegible]
	" " Annie G. Fitz, " " " "	476	57
		1258	86

No. Trial Guard. Am.

G. B. Whitney

EXECUTOR'S ACCOUNT.

Tues. Nov 1886

Rec. Book

Page

Cit. Ret.

E. E. Fife

COMMONWEALTH OF MASSACHUSETTS.

MIDDLESEX, ss. 188 .

Then personally appeared , execut , and made oath that the within account is a just and true account of h administration therein named.

Before me,

....Justice of the Peace.

Mr. Charles F. Fitz,

To S. B. Stebbins, Executor,

Estate of Ellen E. Fitz, Dr.

1886		
Nov.	For Piano.	50.00
	" Furniture.	25.00
	" 1/2 interest in Globe patents,	50.00
	" 1/2 " " copyright of Handbook of Globe	.50
	" 1/2 interest in Manuscript on astronomy.	.50
	" 1/2 interest in sale of copyright of music.	12.50
		138.50
1887, Jany 13,	Cash	338.06
		$476.56

Settled

S. B. Stebbins,

Executor

3800
450
4250
55
3
~~4308~~

4305

338
636